CAL. LAB

INSTRUCTION MANUAL

MODEL 327
DIODE NOISE ANALYZER

For Serial No. 137

QT

• ELECTRONIC INSTRUMENTS

Quan-Tech

LABORATORIES INC.

WHIPPANY, N. J.

INSTRUCTION MANUAL

MODEL 327
DIODE NOISE ANALYZER

For Serial No. 137

Quan-Tech LABORATORIES, INC.

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CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY

Quan-Tech Laboratories, Inc. warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Electronic tubes and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misadjustments, misuse, or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

Calibration checks of this instrument can easily be made in accordance with the instruction manual. Routine readjustments should never be attempted. If, however, the instrument has been damaged and requires recalibration or alignment, explicit calibration procedures as defined in the instruction manual must be followed.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

The instruments should be packed in their original containers, or in a strong exterior container and surrounded by two inches of shock absorbing material.

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SECTION 1
GENERAL

A. DESCRIPTION

The Quan-Tech Model 327 Diode Noise Analyzer was developed specifically to measure the electrical noise generated within back - biased semiconductor diodes. This instrument is also useful however in detecting defects in forward biased diodes and in measuring low frequency noise in electrolytic capacitors.

Noise voltage is monitored by front panel meters at 10 cycles and 1kc simultaneously and a broadband noise voltage is available at a jack at the rear of the chassis for oscilloscope presentation. In addition to the noise metering, the Model 327 provides front panel metering for dynamic impedance, DC voltage and DC current.

The oscilloscope presentation of broadband noise voltage and the capability of the Model 327 to automatically sweep the applied voltage and/or current, provide a means of obtaining diode noise information quickly over a wide range of DC operating conditions. The sweeping technique has been proven to yield much more informative data than the single DC level method, and in fact the limit on the information obtainable using this method falls for the most part on the operator.

B. SPECIFICATIONS

Noise Range:	0.03 to 1000 microvolts RMS per root cycle full scale.
Band Pass:	Internal amplifier response 5 cycles to 100 kc. Noise voltage measured at 10 cycles and 1 kc simultaneously. Low frequency response of broadband noise output is governed by the RAMP switches.
D.C. Voltage:	0 to 500 volts continuously variable. Metered in five ranges: 10V, 30V, 100V, 300V and 1000V full scale
D.C. Current:	0 to 100 milliamperes. Metered in nine ranges: 10μa, 30μa, 100μa, 300μa, 1ma, 3ma, 10ma, 30ma and 100ma full scale.
Maximum D.C. Power:	Under high voltage and high current conditions, maximum available power is 40 watts.
Ramp:	Power supply swept by internal triangular reference waveform (appears as a voltage and/or current sweep depending upon test diode characteristics). Power Supply may be automatically swept by the RAMP circuitry or manually controlled as a front panel selection.
Impedance:	Dynamic impedance measured on one range from 0 to 300 ohms.
Analog Outputs:	Available at rear of chassis from 'phone jacks and/or multiple pin connector. 0 to 10 VDC for full scale meter reading from DC voltage and DC current. 0 to 1VDC for full scale meter reading from 10 cycle noise, 1kc noise and impedance.
AC Outputs:	10 cycle noise, 1kc noise and broadband noise output.
Auxiliary Outputs:	Negative gate and negative 18VDC regulated.
Power Input:	117 volts, 50-60 cycles.
Dimensions:	11"high, 15"wide, 11"deep overall.
Weight:	40 pounds.

SECTION 2
OPERATION

A. FIRST TIME OPERATION

The procedure given below will enable an operator to energize the Model 327 and make basic diode measurements. It is highly recommended, however, that the remainder of SECTION 2 be read to obtain a greater understanding of the function of the equipment.

It should be noted that 500 VDC can be applied to the test jig terminals. The operator should be warned of the potential hazard and instructed not to override the safety interlock switch operated by the test jig cover.

1. Plug the Model 327 into a suitable supply of 117V, 50-60 cycle line power and turn the power switch to ON.

2. Turn the VOLTAGE control fully counterclockwise.

3. Set the current range switch to a full scale position which does not exceed the current rating of the diode to be tested.

4. Open the test jig cover and insert the diode in the test terminals. (Terminal on the right side is positive voltage.) Close the jig cover all the way to activate the protective interlock.

5. Set the IMPEDANCE switch to the center position (off) and the RAMP OFF switch to the up position (OFF).

6. Advance the VOLTAGE control clockwise to obtain the desired current or voltage for the diode under test.

7. Adjustment of the VOLTS switch, the current range switch and the VOLTAGE control must always be such that the d-c current and voltage meters read on scale.

8. Set the NOISE VOLTAGE switch and the MULTIPLIER switch for on scale meter readings of the 1 Kc and 10 cycle NOISE meters respectively. These meters now read the noise voltage spectral density at 1 Kc and 10 cycles. (Noise voltage referred to a one cycle bandwidth at 1 Kc and 10 cycles.)

9. To measure impedance in the range of two to 300 ohms the IMPEDANCE switch may be set in either the upper (lock on) or lower (momentary on) position. It should be noted that the diode impedance may be shunted by internal circuitry. This condition is described more fully in SECTION 2-B-5 following.

10. For automatic voltage and/or current sweep through the use of the RAMP controls refer to SECTIONS 2-B-4, 2-C-2 and 2-D.

B. FRONT PANEL METERS AND CONTROLS

1. VOLTAGE Control

The front panel VOLTAGE control is in fact a true voltage control when the test jig terminals are open circuited. Under short circuit conditions of the test terminals (and the jig cover closed to activate the protective interlock) the VOLTAGE control will give the indications of being a current control. The function of this control then varies between the two extremes dependent upon the DC characteristics of the component in the test jig.

2. VOLTMETER

The panel voltmeter indicates the DC voltage across the test jig terminals when the jig cover is closed, and the open circuit power supply voltage when the jig cover is open. Automatic voltage limiting is accomplished in the voltmeter circuit and is controlled by the position of the VOLTS switch. The VOLTS switch normally functions as a simple voltmeter multiplier selector and does not determine the power supply voltage except when that voltage is in excess of the voltage range selected. If for example the VOLTAGE control is adjusted for full scale voltmeter deflection and then the VOLTS switch is turned to the next lower voltage range, the power supply voltage will be reduced automatically to approximately 10% above the full scale voltage for the lower position.

3. AMMETER and Current Range Switch

The panel ammeter indicates the current through the component in the test jig terminals. Note that the positive test jig termi-

3. AMMETER and Current Range Switch (Cont'd)

nal is disconnected from the power supply and shunted to ground by the interlock switch when the jig cover is open. The current range switch can change the current through the device under test in contrast to the VOLTS switch which cannot change the voltage. As the dynamic impedance of the device under test approaches zero, the function of the internal power supply approaches that of a constant current supply. With a short circuit in the test jig terminals the current is changed in 3:1 steps by switching the current range switch. The ammeter circuit automatically limits the steady state current to approximately 10% above the full scale ammeter range selected in much the same way as the over voltage limit discussed above.

4. RAMP, RAMP OFF and RAMP RANGE Switches

These three switches select the automatic DC sweeping characteristics of the Model 327. With the RAMP OFF switch in the center (on) position the internal power supply is swept up and down in an essentially symmetrical fashion. The sweep rate is selected with the RAMP switch (FAST, MED., SLO.), the upper limit of the sweep is determined by the position of the VOLTAGE control and the lower limit of the sweep is determined by the position of the RAMP RANGE switch.

5. IMPEDANCE

With the IMPEDANCE switch in either the upper (lock on) or lower (momentary on) position, a 10Kc sine wave signal is applied to the component under test. The 10Kc impedance from 0 to 300 ohms is indicated by the IMPEDANCE meter. It should be noted that the component under test is shunted by an isolating resistor whose value is a function of the current range switch. The values of the isolation resistors for the positions of this switch are as follows:

100 ma — 100 ohms	300 μa — 31.6 K ohm
30 ma — 316 ohms	100 μa — 100 K ohm
10 ma — 1 K ohm	30 μa — 316 K ohm
3 ma — 3.16 K ohm	10 μa — 1 Meg ohm
1 ma — 10 K ohm	

Note also that noise measurements should not be made when the impedance measuring circuit is activated.

6. NOISE Meters and Attenuators

Front panel meters read the noise voltage (for a bandwidth of one cycle) at 10 cycles and 1kc simultaneously. The NOISE VOLTAGE switch selects the full scale sensitivity of the 1kc meter and also the amplifier gain for the broadband output. The broadband output is calibrated such that the noise amplification is unity in the 1000 microvolt position and increases in 10db steps as the NOISE VOLTAGE switch is moved counterclockwise.

The full scale sensitivity of the 10 cycle noise meter is that of the 1kc noise meter modified by the position of the MULTIPLIER switch. Example: The NOISE VOLTAGE switch is in the .03 position; the MULTIPLIER switch is in the 3 position. Full scale sensitivity of the 1kc noise meter is 0.03 microvolt and full scale sensitivity of the 10 cycle noise meter is 0.1 microvolt.

It should be noted that the isolation resistor described in the previous paragraph on Impedance represents a shunt on the diode under test. In general, the noise meters will not read the same noise for different positions of the current range switch. The variation in noise read on different positions of the current range switch will depend upon the impedance of the diode under test.

7. SYSTEM NOISE

The system noise of the Model 327 varies with the position of the current range switch, the position of the VOLTAGE control and the impedance of the component under test.

By far the most important parameter in the determination of system noise is the equivalent impedance seen by the preamplifier. In general, this impedance is the isolation resistor selected by the current range switch (values of resistance for each switch position given on page 2 - 2) in parallel with the impedance of the component under test. Typical Curves of System Noise vs: Equivalent Terminating Resistance are given in Figure 2-1. In addition to the system noise level established by the noise voltage and noise current parameters of the preamplifier there is a noise contribution from the main power supply. This part of the total system noise is greatest when a high voltage, low impedance component is in the test jig.

C. MISCELLANEOUS OPERATING INSTRUCTIONS

1. The Model 327 requires 50-60 cycle, 117 volt line power. Severe line transients and RF noise should be avoided as they may cause apparent instabilities in the noise measurements.

2. The internal ramp circuitry is designed to sweep the power supply from the maximum voltage (or current) set by the VOLTAGE control down to a lower limit

determined by the RAMP RANGE switch. To insure proper sweep operation the RAMP OFF switch should be depressed after changing any of the ramp controls to allow resetting of the ramp circuit to the maximum voltage (or current) level.

Time constants in the main power supply limit the rate of change of output terminal voltage to approximately 200 volts per second. The power supply therefore cannot be swept over the entire 500 volt range with the RAMP switch in the FAST position.

3. The Model 327 is capable of supplying up to 40 watts of output power (500 volts at 80 ma. or 400 volts at 100 ma.). The operator should be warned of the potential hazard and instructed not to override the safety interlock switch operated by the test jig cover.

4. Care should be taken to avoid the application of excessive power to the component to be tested by proper setting of the power supply controls. It should be noted that transient currents in excess of the full scale current range can exist in the component under test if the component exhibits a negative resistance characteristic. Although the input circuitry of the Model 327 is protected, severe transients and overloads are not recommended.

D. OSCILLOSCOPE DISPLAY

It is quite informative to display the broadband noise output as a function of the DC current or DC voltage on an oscilloscope. This may be done by connecting to the appropriate jacks at the rear of the unit. An oscilloscope such as the Tektronix Model 503, equipped with a long persistence tube is ideal. Connect the broadband output from the Model 327 to the vertical scope input (vertical sensitivity 1 volt/cm) and either the voltage analog or current analog to the horizontal scope input. (Both of these analog outputs are ten volts DC for full scale panel meter reading.)

The noise pattern is more easily viewed if the up-sweep in current or voltage is offset from the return sweep. A gate voltage is available from P702 to provide a synchronized offset. This gate may be attenuated with a resistive divider of 10,000 ohms or more impedance and applied to the vertical axis if a differential scope such as the Tektronix Model 503 is used.

E. REMOTE TEST JIG

If the test jig supplied with the Model 327 is not adequate for the diode to be tested, the jig may be removed by loosening the screws under the two plug buttons on the panel of the jig. The original jig unplugs, allowing an extension cable to be used either with the original or a custom made jig. The extension cable should not exceed a few feet in length due to limitations of capacitance and shielding. In the operation of a remote jig, care should be taken to remove the high voltage from the terminals for operator safety.

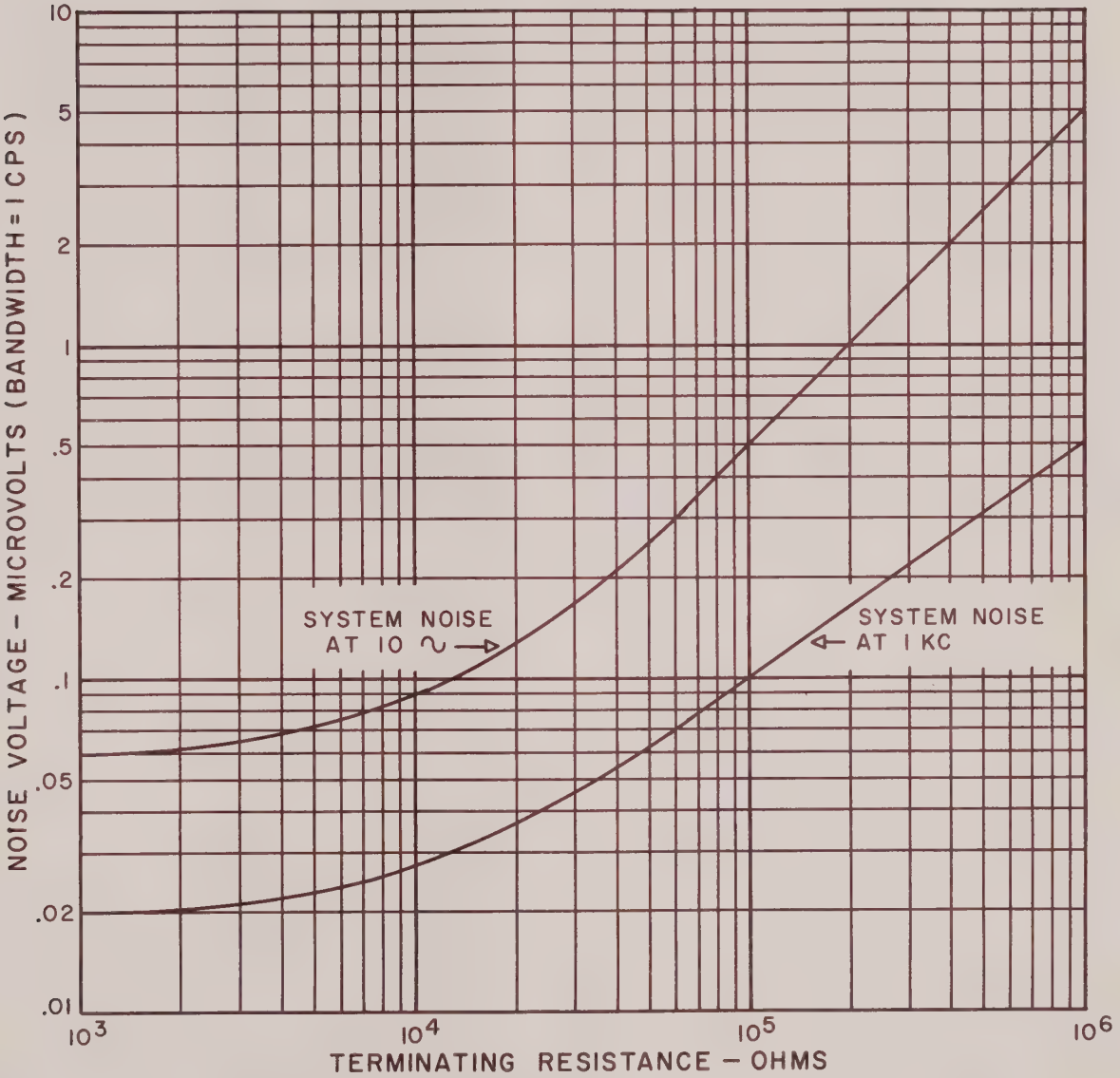


FIGURE 2-1 TYPICAL CURVE
SYSTEM NOISE VS INPUT TERMINATING RESISTANCE

SECTION 3
THEORY OF OPERATION

A. GENERAL

Although the Model 327 Diode Noise Analyzer is a complex instrument, the operation can be readily understood if the individual components or building blocks are taken as separate units. This approach will be valuable not only in understanding the operation of the instrument, but also in the event that servicing is necessary. It should be pointed out that the limits of design of this instrument approach those theoretically possible with existing components; therefore, some deviation in sensitivity and operation between units is to be expected.

A Simplified Block Diagram of the Model 327 is given in Figure 3-1. A variable constant voltage power supply is connected across the diode under test in series with an isolation resistor (selected by the current range switch). The power supply voltage may be varied manually through the use of the VOLTAGE control on the front panel or cyclically varied through the use of the internal ramp circuitry. The diode noise voltage is monitored across the isolation resistor, effectively in parallel with the diode under test. This method of monitoring must be considered when specifying absolute noise measurements, since the isolation resistor does represent a finite shunt across the diode. In addition to isolating the diode under test from the main power supply, the isolation resistor determines the operating current range. In normal operation the isolation resistor supplies a zero to ten volt DC swing to the amplifier which will correspond to zero to full scale ammeter reading.

The amplifier supplies information to all of the specialized circuits required to give either readout or output information for the monitoring of DC voltage and current, AC impedance, broadband noise, 10 cycle noise and 1kc noise.

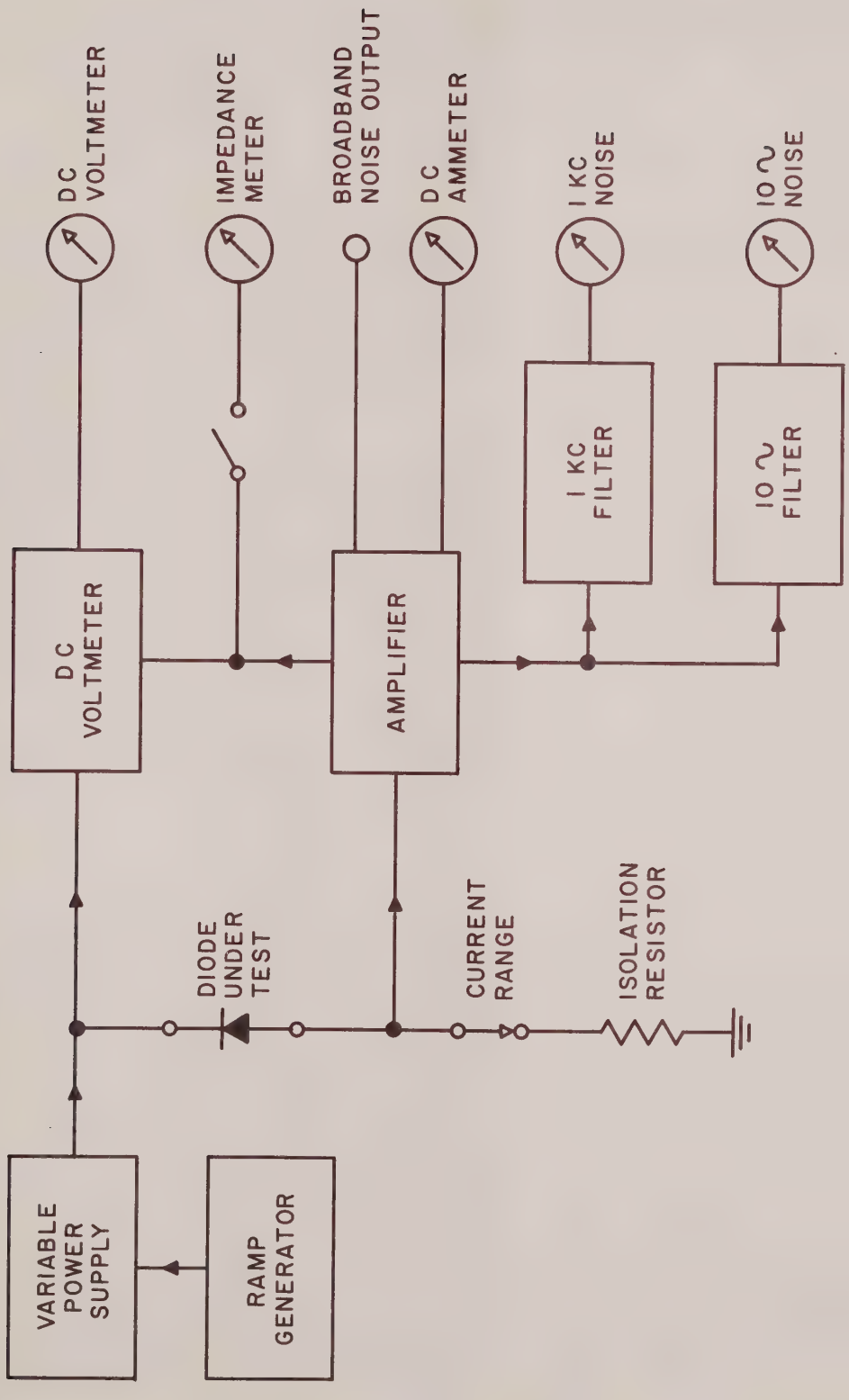


FIGURE 3-1 SIMPLIFIED BLOCK DIAGRAM

SECTION 4
CIRCUIT DESCRIPTION

A. GENERAL

The Detailed Block Diagram, T-4000, indicates the operation of each section of the instrument. In general, the circuitry contained in each block of this diagram is on a separate plug-in printed circuit board or series of boards as in the case of the filters.

B. MAIN SUPPLY AND BLEED SUPPLY – (Schematic T-4001)

The Main Supply is to provide power to the diode under test. The upper portion of the schematic consists of the rectifiers and the pre-regulator filters. On the primary side of transformer T 101 the silicon controlled rectifier, CR105, is operated by additional circuitry to maintain a constant voltage on the power supply pass transistor. In the event the voltage across the pass transistor is reduced below its controlled point, the firing angle of CR105 is increased and more current is drawn from the line. The purpose of V 102 is to supply a constant current bleed in order to discharge the filters of the main supply during operation of the ramp. V 101 acts as a regulator in the cathode of the bleed tube, maintaining this constant current.

C. SCR CONTROL – (Schematic T-4002)

The purpose of the SCR Control is to supply pulse information to the SCR which in turn maintains a nearly constant voltage on the pass transistor. The contact D(4) is attached to the main unregulated negative voltage which is the collector of the pass transistor. The emitter of the pass transistor is connected to ground. R205 and R206 form a voltage divider whose voltage is compared with the voltage at the base of Q202. If the voltage across the pass transistor decreases, Q202 draws more current charging C204. When C204 has reached a sufficient charge it will then fire the unijunction transistor Q201, which is transformer coupled to the SCR. The purpose of Q203 and Q204 is to generate a synchronized dump pulse so that on each half cycle C204 is discharged and the operation of the SCR is synchronized to the line. Q204 receives its information for this synchronization from full wave rectification of the output of the secondary #1 of T 102. Adjustment of the voltage across the pass transistor can be made with R209.

D. +18 VOLT BIAS SUPPLY (Schematic T-4003)

The purpose of this supply is to provide power for the amplifiers, ramp generator, filters and associated circuitry. The heart of this supply is the reference diode CR304. The voltage across this reference is compared with that obtained from the resistive divider R304 and R305. Q301, Q304, Q302 and Q303 consist of two differential amplifiers, the final of which supply Q305 with the error information necessary to maintain a well regulated +18 volts. CR303 is provided to give some pre-regulation for the collector of Q303.

E. -18 VOLT REFERENCE AND BIAS SUPPLY – (Schematic T-4004)

The operation of this supply is identical to the +18 Volt Supply.

F. RAMP GENERATOR – (Schematic T-4005)

The purpose of the Ramp Generator is to supply a triangular voltage to the error amplifier of the main supply. The triangular voltage may be varied in frequency and in amplitude by the ramp and ramp range controls respectively. Q501, Q502 and Q503 form a square wave generator whose frequency is controlled by the selection of capacitors in switch S502A. These capacitors are charged through R506 until the unijunction transistor Q501 has reached its firing point, at which time the base of Q502 is reduced to approximately -18 volts. This discharge voltage is transferred through C505 and biases Q503 beyond cut-off. The circuit remains in this condition until the capacitor is discharged through R509, at which time the unijunction releases and C505 begins its charge cycle again. It is necessary that the charge time of this capacitor be longer than the discharge time and form a slightly asymmetrical output from Q503. The purpose of this is to allow the generated differential wave to always remain for a small part of this period at the negative side of the waveform. When Q503 is in full conduction a constant current is supplied to the emitter of Q504 which charges C506 and the other capacitors selected with S502B. On turning off Q503 the capacitor C506 is discharged by Q506. The rate of charge and discharge of C506 is obtained from the ramp range switch, S503. Q505 serves as an impedance converter to supply a low impedance triangular waveform to the error amplifier.

G. ERROR AMPLIFIER – (Schematic T-4006)

The purpose of the Error Amplifier is to provide a well regulated voltage to the diode under test. The difference in the voltage between the bases of Q602 and Q603 is amplified through Q604 and Q605 to the base of the pass transistor Q606. Diodes CR601 and CR602 are for protection of the input of this amplifier. Q601 supplies a leakage buckout current to reduce the thermal error in the amplifier. The voltage at the base of Q602 is obtained from the voltage dividers R603 and R605. When the ramp generator is in operation a variable current is passed through this divider and as a result the output voltage of the supply can be controlled over a wide range. It should be noted at this point that the maximum rate of sweep in volts per second is limited by the ability to discharge both the output capacitor C602 and the main filter capacitors, C104 and C105, by the constant current bleed of V102. This rate is approximately 200 volts per second.

H. 10 KC OSCILLATOR, PRE-AMPLIFIER AND AMMETER – (Schematic T-4007)

The 10 KC Oscillator is a straightforward single transistor oscillator whose output is stabilized by reference diode, CR701. The purpose of this oscillator is to supply the calibrating signal to the diode under test for impedance measurement. The Pre-Amplifier portion of the circuitry has a selected low noise silicon transistor in the input stage. The amplifier formed by Q702, Q703, and Q704 provides unity gain and impedance transformation in order to drive the following amplifiers and metering circuitry. Q705 and Q706 provide further isolation and drive the ammeter, M701. The maximum allowable voltage for these amplifiers is controlled by the dump transistor, Q707, which is adjusted to block the error amplifier when a voltage of approximately 11 volts is obtained. If large surges are incurred due to a faulty test component, or other irregularities at the input, the protection diodes, either CR703 or CR704 and CR705, will conduct. CR703 is clamped by CR702 at 12 volts, thus providing protection of the amplifier input. The components in the front section of this amplifier assembly are carefully selected for minimum noise parameters including the protective diodes. It is possible, due to aging, that these components may deteriorate with time and necessitate replacement.

I. VOLTMETER – (Schematic T-4008)

The Voltmeter circuit is a differential amplifier which measures the voltage across the diode under test. Since both terminals of the diode are above ground, it is necessary for the voltmeter to float. The zero adjustment of the voltmeter may be made with R811 and the gain of the differential amplifiers formed by Q801, Q802, Q804 and Q805 may be adjusted by R823 allowing the proper full scale calibration. Q806 is an impedance converter used to drive M801 as well as the DC voltage analog. If the output of the voltmeter circuit exceeds approximately 11 volts, the dump transistor Q807 conducts and disables the error amplifier.

J. IMPEDANCE METER AMPLIFIER – (Schematic T-4009)

In the Impedance measuring condition the 10KC signal across the diode under test is amplified by the pre-amplifier and applied to the series resonant tank circuit, C902 and L901, thus rejecting unwanted noise from diodes which could cause an indication on the impedance meter. Q901 and Q902 form a two section feedback amplifier. The feedback is obtained through the rectifiers CR902 and CR901 and their associated circuitry and is applied to the gain determining resistor R905.

K. FIRST AMPLIFIER – (Schematic T-4010)

The First Amplifier is driven from the pre-amplifier through the high pass filters as selected by the ramp switch. The purpose of this is to attenuate the harmonics generated by the ramp in its selected sweep speed. The amplifier consists of four transistors, Q1003 and Q1004 being used as a single ended push-pull pair. Overall feedback is applied from the output for gain stabilization.

L. SECOND, THIRD, AND BROADBAND AMPLIFIERS – (Schematic T-4011)

The Second and Third Amplifiers are similar in operation to the First Amplifier. Protective diodes are supplied at the input to all amplifiers to prevent excessive overload which would cause blocking in the output circuitry. The output of the Third Amplifier drives the broadband noise amplifier, the 1Kc filter and the attenuator assembly with the 10 cycle filter. It should be noted that the broadband amplifier is a simple phase inverter having unity gain. The reason for the phase inversion is that the diode under test is measured at its negative terminal rather than the positive terminal, and misleading interpretation of the noise would be obtained if this were not done.

M. 10 CYCLE FILTER ATTENUATOR AND FIRST SECTION – (Schematic T-4012)

Additional attenuation is provided for the 10 Cycle Filter since noise phenomena has a spectral response which may vary from a slope of 1 to $1/f^2$ in power. The entire filter consists of a three section maximumly flat design geometrically centered at 10 cycles and having a bandwidth of 10 cycles. Q1202 and Q1203 form a negative impedance converter. Reference should be made to the Active Filter Section Equivalent, Figure 4-1, for the frequency determining network. The frequency determining elements are

R1207, C1201, R1210 and C1202. The Q of this active tank circuit is adjusted with R1212. Q1204 provides amplification and a current source to operate the second section of the filter.

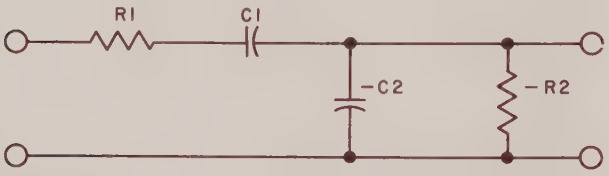


FIGURE 4-1 ACTIVE FILTER SECTION EQUIVALENT

N. 10 CYCLE FILTER, SECOND SECTION AND THIRD SECTION – (Schematic T-4013)

The theory of operation of the Second and Third Sections of the filter is identical to that of the First Section. However, the frequency determining networks and their respective Q's are different, to conform to the filter design. Proper alignment of the filter is discussed in the section on Maintenance and Calibration.

O. 10 CYCLE FILTER METER AMPLIFIER AND RECTIFIER – (Schematic T-4014)

The Meter Amplifier is similar in design to the noise channel amplifiers. However, in series with the feedback loop there is a full wave bridge rectifier consisting of CR1401, CR1402, CR1403, and CR1404. The rectified output of this is filtered and drives the 10 cycle noise meter. To provide a single ended analog output the voltage across the metering circuit is amplified by Q1405 and Q1406. Q1407 provides a constant current for this differential pair and the zero offset at the analog output is adjustable by R1421. The calibration may be adjusted by R1417. A monitor point for the 10 cycle noise is provided at the feedback point of the meter amplifiers. The gain of the measuring amplifier is adjusted by R1415.

P. 1 KC FILTER – (Schematics T-4015, T-4016, T-4017)

The 1 KC Filter Assembly, including its metering circuit, is identical to the 10 Cycle Filter Assembly with the exception of the values of the frequency determining components of the filter and the time constants in the metering circuit.

SECTION 5
MAINTENANCE AND CALIBRATION

A. NORMAL OPERATION

The various functions of the Model 327 may be quickly checked for normal operation without the use of external test equipment. If close tolerance checks are to be made the instrument should be allowed to warm up for at least fifteen minutes. The following procedure will indicate normal overall performance.

1. D.C. AMMETER

a. Place a shorting wire in the test jig and close the jig cover. The ammeter should read up-scale approximately 10 to 30% of full scale with the front panel VOLTAGE control fully counterclockwise.

b. Set the VOLTAGE control for full scale ammeter deflection. The ammeter should remain at full scale deflection for all positions of the current range switch. This test will indicate normal operation of the ammeter circuit and give a rough measure of the internal power supply load regulation from 10 microamperes to 100 milliamperes output current.

2. D.C. VOLTMETER

a. Leave the VOLTAGE control set for full scale ammeter deflection as in the previous check. Set the current range switch to the one milliampere (1 MA) position.

b. Remove the shorting wire from the jig terminals. The voltmeter should read 10 volts with the jig cover open or closed. CAUTION: The voltage indicated on the voltmeter is present at the test jig connector when the jig is removed. It is recommended that the Model 327 be turned off when connecting or disconnecting the jig.

3. IMPEDANCE METER

a. With the test jig terminals open circircuited, set the current range switch to the 100 milliampere (100 MA) position.

b. When the front panel IMPEDANCE switch is pressed either up or down the IMPEDANCE meter should read 100 ohms. Tune C901, from the rear of the instrument, to give maximum up scale indication if required.

4. NOISE CHANNELS

a. Leave the test jig terminals open circuited as in the previous check, close the jig cover, and set the IMPEDANCE switch to the center (off) position.

b. Place the current range switch in the 100 milliampere (100 MA) position. System noise should be approximately 0.02 microvolt at 1Kc and approximately 0.06 microvolt at 10 cycles.

c. Turn the current range switch counterclockwise; in general the system noise should increase with each additional counterclockwise position change. Approximate system noise readings for each of the current range positions may be obtained from FIGURE 2-1.

5. POWER SUPPLY

a. Place the VOLTS switch in the 100 volt position; RAMP RANGE switch in the full clockwise position; RAMP-OFF switch in the lock OFF position; and open circuit the test jig terminals.

b. Advance the VOLTAGE control clockwise to 100 volts as indicated on the panel voltmeter.

c. Place the RAMP speed switch in the FAST position; and the RAMP-OFF switch in the center (on) position. The voltmeter should indicate that the internal power supply is sweeping between zero and 100 volts with a sweep waveform which is approximately triangular.

d. TURN the RAMP RANGE switch fully counterclockwise and press the RAMP-OFF switch down to the momentary OFF position to allow the supply voltage to return to 100 volts. Release the RAMP-OFF switch to the center on position. The voltmeter should indicate that the internal power supply is sweeping from the manually set maximum voltage of 100 volts down to approximately 80% of the manual set or 80 volts and then back to 100 volts.

e. Repeat steps c and d with the RAMP speed switch in the MED and SLO positions.

f. Set the RAMP-OFF switch to OFF, and the VOLTS switch to the 1000 volt position. CAUTION: Make sure that the test jig cover is closed.

g. Advance the VOLTAGE control to the full clockwise position. The voltmeter should indicate that the maximum internal power supply is slightly over 500 volts.

h. Return the VOLTAGE control to the full counterclockwise position. Place a 10K ohm resistor in the test jig terminals; set the current range switch to the 1 MA position; the VOLTS switch to the 30 volt position, and close the test jig cover.

i. Advance the VOLTAGE control clockwise, the ammeter should go off scale and the voltmeter should show that the the current limit circuit has limited the current to a value slightly greater than the full scale current reading.

j. Set the VOLTS switch to the 10 volt position and the current range switch to the 3 MA position. The voltmeter should be off scale and the ammeter should be reading slightly greater than 1 ma. indicating proper functioning of the voltage limiting circuitry.

B. MAINTENANCE

1. GENERAL

It is recommended that the case be removed from the Model 327 only after the NORMAL OPERATION checks given above have been performed and the results indicate the necessity of doing so. Servicemen are cautioned not to change calibration adjustments unless it has been established that adjustment is required.

Servicing is greatly simplified by the packaging technique employed. Small isolated circuits are usually found on one small printed circuit assembly which can be extended from the module through the use of the applicable extender board provided. CAUTION: Main power should be turned off when connecting or disconnecting the printed circuit assemblies to avoid damaging semiconductor components through the transient voltages thus created. Care should be taken to insure proper alignment of the printed circuit assembly when placing it in the socket (i.e. it is possible to reverse the assembly physically thereby causing damage when power is applied).

When measurements are being made on the printed circuit assemblies, great care should be taken to avoid shorting adjacent connections as semiconductor components are very susceptible to damage through this type of misuse. In soldering to the assemblies, have the iron only hot enough to make a rapid clean joint, and do not apply force which would tend to push the copper away from the board.

There are high voltages present in the Model 327. The main diode test supply is capable of 500 volts at 80 ma. The vacuum tube bleed supply is a fixed supply of approximately 150 volts. This instrument should therefore be treated with the same respect as any vacuum tube instrument containing similar voltages.

2. REMOVAL OF INSTRUMENT FROM CASE

Remove the four (4) binder head screws from the bottom of the case and gently slide the instrument out the front.

C. DETAILED CALIBRATION

The following is a detailed procedure giving sufficient information to calibrate the Model 327. Some of the adjustments described are made at the factory through the selection of fixed resistors. These adjustments should not have to be changed in the field unless related components have been replaced. In the event that resistors are replaced, care should be taken to use resistors of the same type as those used in initial construction and/or calibration. In general, resistors calling for a plus or minus one per cent tolerance on the schematic diagram must also have a noise index of less than -40 db. There are exceptions to this rule but when in doubt adherence to this noise specification will insure proper circuit performance.

NOTE: In the following procedure four digit numbers without an identifying symbol letter preceding them refer to printed circuit board assembly numbers.

1. +18 Volt Bias Supply (3803)

   a. Select R306 for +18 volts between pin 8 of 3803 and chassis ground.

2. -18 Volt Reference and Bias Supply (3804)

   a. Select R406 for -18 volts between pin 9 of 3804 and chassis ground.

3. Voltmeter Electrical Zero (3808)

   a. Set the current range switch to the 1 MA position; VOLTS switch to the 100 volt position; place a shorting wire in the test jig terminals and close the jig cover.

b. Adjust R811 for electrical zero of the panel voltmeter.

4. Voltmeter Calibration (3808)

a. Leave the front panel controls the same as for the previous adjustment, set the VOLTAGE control for 100 volts across test jig terminals (as read on external meter).

b. Adjust R823 for full scale voltmeter deflection (100 volts).

c. If adjustment in either 3 or 4 was considerable, repeat steps 3 and 4 to eliminate interaction of the zero and calibration adjustments.

5. Impedance Meter Calibration (3809)

a. Open circuit the test jig terminals, set the current range switch to the 100 MA position and place the IMPEDANCE switch in the lock-up position.

b. Adjust C901 through the hole in the rear of the chassis for maximum impedance indication on the IMPEDANCE meter.

c. Adjust R712 on 3809 for 100 ohms IMPEDANCE meter reading.

6. Noise Meter Electrical Zero (10 cycle filter, 3800; 1 Kc filter 3801)

a. Set the current range switch to the 100 MA position; NOISE VOLTAGE switch to the 1000 microvolt position; 10 cycle MULTIPLIER switch to the 100 position and open circuit the test jig terminals.

b. Select R1420 (3800) for electrical zero of the 10 cycle NOISE meter.

c. Select R1720 (3801) for electrical zero of the 1 Kc NOISE meter.

7. Noise Channel Analog Zero and Calibration (10 cycle filter, 3800; 1 Kc filter, 3801)

a. Set the current range switch to the 100 MA position; NOISE VOLTAGE switch to the 1000 microvolt position; 10 cycle MULTIPLIER switch to the 100 position and open circuit the test jig terminals.

b. Adjust R1421 (3800) for zero volts dc at pin 3 of the output connector, P702, at the rear of the chassis.

c. Adjust R1721 (3801) for zero volts dc at pin 4 of the output connector, P702, at the rear of the chassis.

d. Apply sufficient 10 cycle sine wave voltage at the negative test jig terminal (as in noise meter calibration approximately 2.88 mv), to give full scale indication on the 10 cycle noise meter.

e. Adjust R1417 (3800) for one volt dc at pin 3 of the output connector, P702, at the rear of the chassis.

f. Apply sufficient 1 Kc sine wave voltage at the negative test jig terminal (as in noise meter calibration approximately 28.8 mv), to give full scale indication on the 1 Kc noise meter.

g. Adjust R1717 (3801) for one volt dc at pin 4 of the output connector, P702, at the rear of the chassis.

8. Noise Meter Calibration (10 cycle filter, 3783; 1 Kc filter, 3784)

The noise meter calibration may be accomplished in either of two ways. The simplest of the two is to apply a known magnitude of white noise voltage between the negative test jig terminal and chassis ground and adjust the gain of the filter amplifiers to give the correct noise voltage reading. The following procedure utilizing the Quan-Tech Laboratories Model 420 Random Noise Generator is done in this way.

a. Set the Model 327 current range switch to the 10 μa position; NOISE VOLTAGE switch to the 1000 microvolt position and the 10 cycle MULTIPLIER switch to the one (1) position.

b. Set the Model 420 METER MULTIPLIER switch to the X1000 position; the termination switch to the 600 ohm TERM. position and the VARIABLE output control for full scale meter indication. (1000 microvolts per root cycle of bandwidth output.)

c. Connect the high side of the Model 420 output to the negative test jig terminal of the Model 327 and the ground side to the Model 327 chassis ground.

d. Adjust R1415 on the inside end of the 10 cycle filter connector board for full scale reading of the 10 cycle NOISE voltage meter.

e. Adjust R1715 on the inside end of the 1 Kc filter connector board for full

scale reading of the 1 Kc NOISE voltage meter.

The second method of calibration for the noise channels is the known gain, known bandwidth method. This method involves the measurement of filter bandwidth and the application of correction factors to obtain correction for the averaging meter circuits and conversion to equivalent noise bandwidths for this particular filter design. The gain parameter in this application is unity if the NOISE VOLTAGE switch is placed in the 1000 microvolt position. The following equation is used to obtain the RMS sine wave calibrating voltage for full scale meter reading on each of the two noise channels:

$$e_{cal} = (f_2 - f_1)^{1/2} (0.912) \text{ mv.}$$

where f_2 and f_1 are the upper and lower half power frequencies of the filter in question and 0.912 is the correction factor for the metering circuit and conversion of 3 db sine wave bandwidth to equivalent noise bandwidth for a three section maximally flat filter design.

Calibration of the noise channels is done individually when using this method. The calibrating voltage (e_{cal}) is applied to the input of the Model 327 and the filter amplifier gains are adjusted in the same manner as in the previous procedure described for the Model 420 calibrated noise source.

Typical calibrating voltages for the two filters are 28.8 mv for the 1 Kc filter and 2.88 mv for the 10 cycle filter but these will vary slightly from unit to unit.

9. Frequency Response Alignment: 10 cycle and 1 Kc filters, (3783 and 3784)

Both filters are constructed from the same basic filter design. It is a three section maximally flat design with an overall Q of unity. The overall filter shape and center frequency is obtained through the use of precision frequency determining elements and the adjustment of the three individual Q values in active circuits.

The following is the procedure for aligning the 1 Kc filter. The procedure is identical for the 10 cycle filter with the obvious numbers changed accordingly.

NOTES:

Turn off the main power when changing the position of the printed circuit assemblies.

In all places where an audio oscillator is called for the driving impedance of the oscillator must be less than 65 ohms and the level should be approximately 30 mv adjusted slightly for convenience in making the measurement.

The input and output voltages to be measured for the gain adjustments should be measured with a high impedance voltmeter (greater than 100K ohms).

The object of this procedure is to set the individual Q values for each section. The gain adjustment described bears a direct relationship to the Q and is therefore a simplified method of alignment.

a. Remove all the printed circuit assemblies from the filter connector board.

b. Place the third section board assembly, 3799, in the socket intended for the first section assembly.

c. Connect an audio oscillator between pin 2 of 3799 and chassis ground.

d. Tune the oscillator frequency for maximum output voltage at the emitter of Q1608 (1540 cycles ±10%).

e. Adjust R1616 for a voltage gain of 3.74 from pin 2 to the emitter of Q1608 (Q for this section is 2.19).

f. Place 3799 in the socket intended for 3798 and place 3798 in the socket intended for 3797.

g. Connect an audio oscillator between pin 2 of 3798 and chassis ground.

h. Tune the oscillator frequency for maximum output voltage at the emitter of Q1604 (1 Kc ±10%).

i. Adjust R1606 for a voltage gain of 1.20 from pin 2 to the emitter of Q1604 (Q for this section is unity).

j. Remove 3798 and place 3797 in the socket intended for 3797.

k. Connect an audio oscillator between pin 2 of 3797 and chassis ground.

l. Tune the oscillator frequency for maximum output voltage at the emitter of Q1504 (650 cycles ±10%).

m. Adjust R1506 for a voltage gain of 3.26 from pin 2 to the emitter of Q1504 (Q for this section is 2.19).

n. Place 3797, 3798 and 3799 in their intended sockets.

o. Connect an audio oscillator between pin 2 of 3797 and chassis ground.

p. Trim a minimum number of the three adjustments (R1506, R1606 and R1616 to obtain flat top response at the emitter of Q1608 on 3799 when the audio oscillator frequency is swept over the pass band of 650 to 1650 cycles. (The sine wave 3 db down frequencies are approximately 650 cycles and 1650 cycles.)

NOTE: If the filter alignment a through p above has been performed and R1506, R1606 and/or R1616 have been changed, paragraph 8, "Noise Meter Calibration" should be performed also.

10. SCR Power Supply (3802, 3805)

a. Set RAMP-OFF switch to OFF, VOLTAGE control fully counterclockwise and open circuit test jig terminals.

b. Adjust R209 (3802) for 25 volts dc from the collector (case) of Q606 to chassis ground. Q606 is mounted on the bottom of the side of the main chassis with three other power semiconductor devices.

c. Set the VOLTS switch to the 1000 volt position; turn the VOLTAGE control fully clockwise.

d. Select R604 (3805) for voltmeter reading slightly greater than 500 volts (approximately 510-520 volts).

11. Ramp Generator (3806)

a. Set RAMP RANGE switch to the FAST position; RAMP-OFF switch to the center (on) position; VOLTAGE control fully counterclockwise and open circuit the test jig terminals.

b. Select R506A for Q503 on time of 1 second.

c. Select R509A for Q503 off time of 0.9 second.

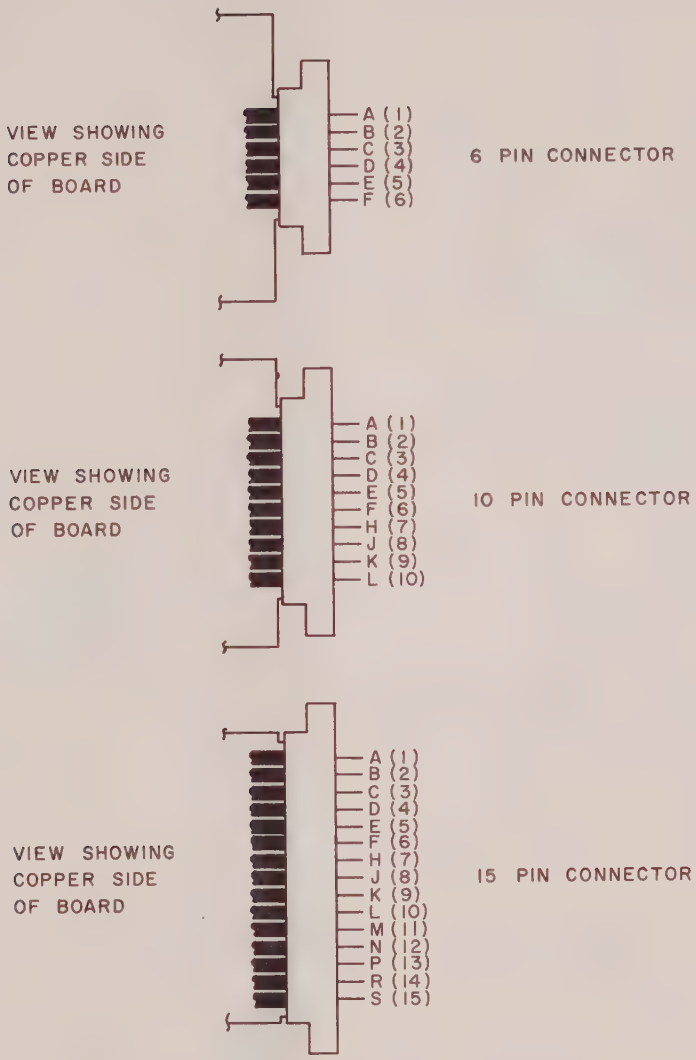


FIGURE 5-1 PRINTED CIRCUIT BOARD CONNECTOR LUG IDENTIFICATION

SCHEMATIC LEGEND

k = 1000

⊘ = Screw Driver Adjustment

▭ = Front Panel Control

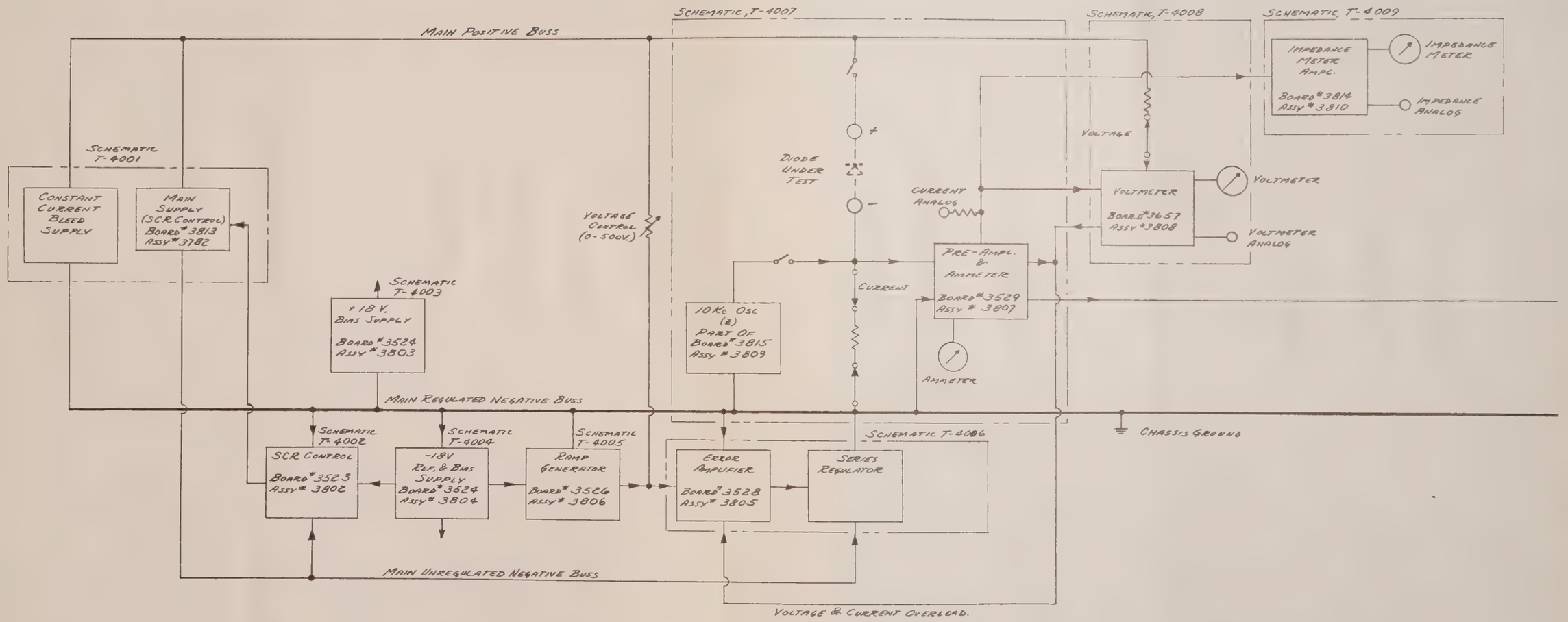
* = Factory Select

Unless Otherwise Specified:

All Resistances in Ohms

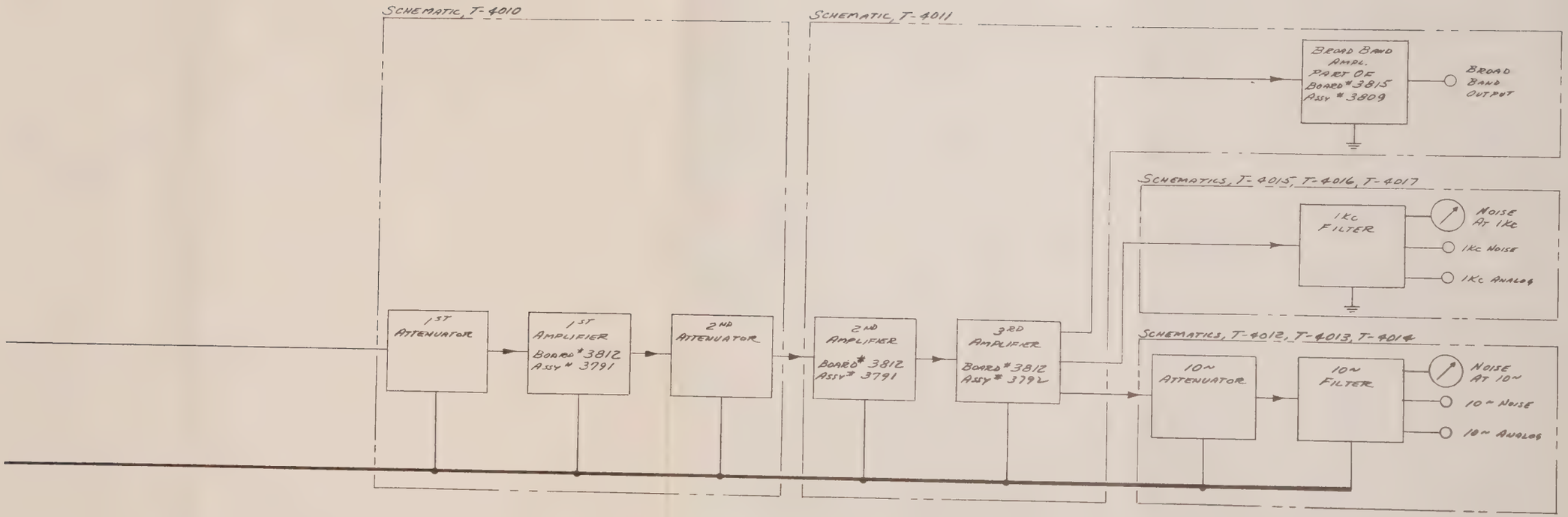
All Resistors 1/2 Watt

All Capacitances in Microfarads


SCHEMATIC, T-4007
SCHEMATIC, T-4008
SCHEMATIC, T-4009
MAIN POSITIVE BUSS
SCHEMATIC T-4001
CONSTANT CURRENT BLEED SUPPLY
MAIN SUPPLY (SCR CONTROL) BOARD # 3813 ASSY # 3782
VOLTAGE CONTROL (0-500V.)
DIODE UNDER TEST
+
-
CURRENT ANALOG
VOLTAGE
IMPEDANCE METER AMPL. BOARD # 3814 ASSY # 3810
IMPEDANCE METER
IMPEDANCE ANALOG
VOLTMETER BOARD # 3657 ASSY # 3808
VOLTMETER
VOLTMETER ANALOG
PRE-AMPL. & AMMETER BOARD # 3529 ASSY # 3807
CURRENT
AMMETER
SCHEMATIC T-4003
+18 V. BIAS SUPPLY BOARD # 3524 ASSY # 3803
10 Kc OSC (2) PART OF BOARD # 3815 ASSY # 3809
MAIN REGULATED NEGATIVE BUSS
CHASSIS GROUND
SCHEMATIC T-4002
SCHEMATIC T-4004
SCHEMATIC T-4005
SCHEMATIC T-4006
SCR CONTROL BOARD # 3523 ASSY # 3802
-18V REF. & BIAS SUPPLY BOARD # 3524 ASSY # 3804
RAMP GENERATOR BOARD # 3526 ASSY # 3806
ERROR AMPLIFIER BOARD # 3528 ASSY # 3805
SERIES REGULATOR
MAIN UNREGULATED NEGATIVE BUSS
VOLTAGE & CURRENT OVERLOAD.

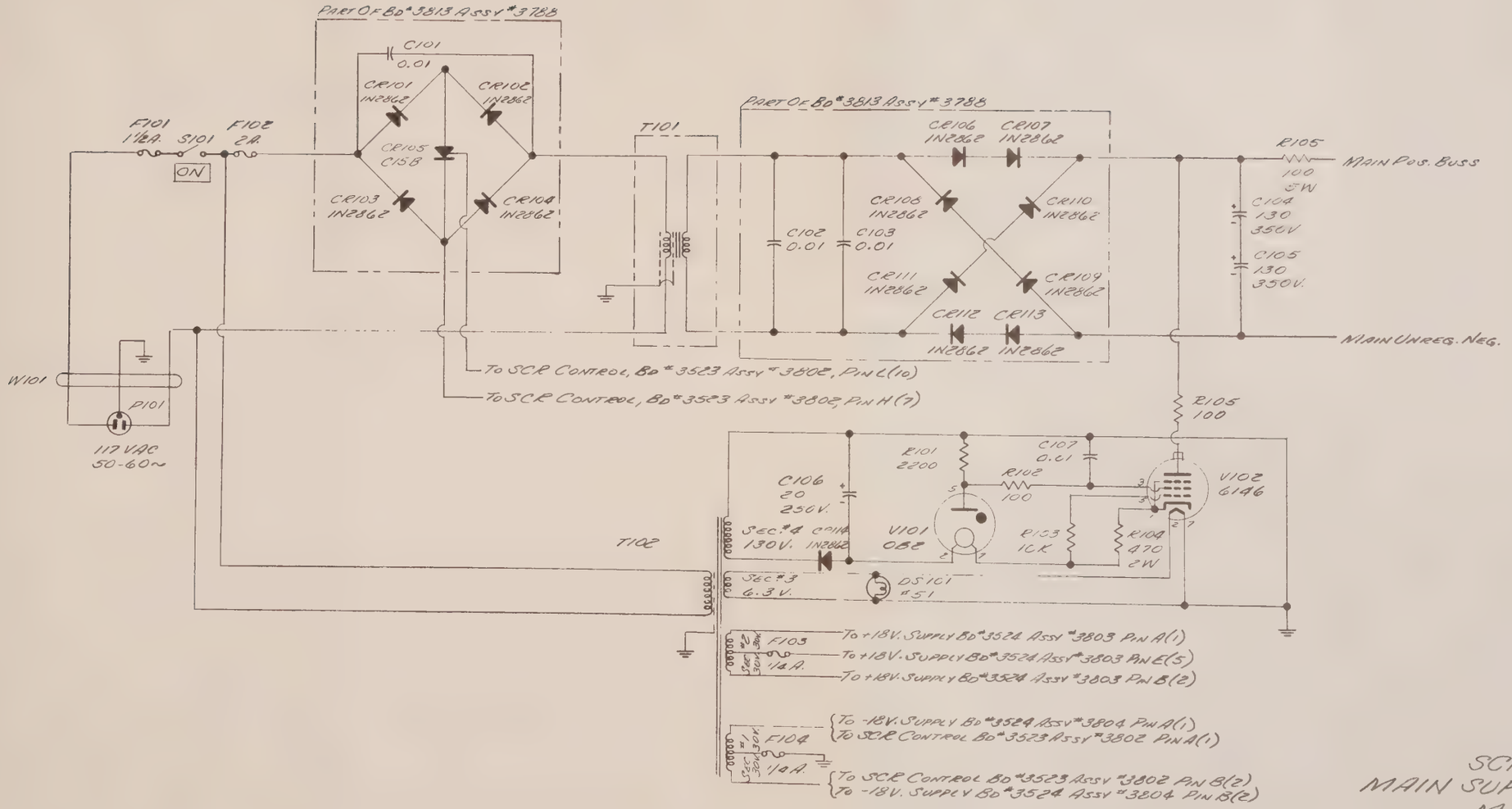
DETAILED BLOCK DIAGRAM MODEL 327

T-4000-A
SHEET 1 OF 2



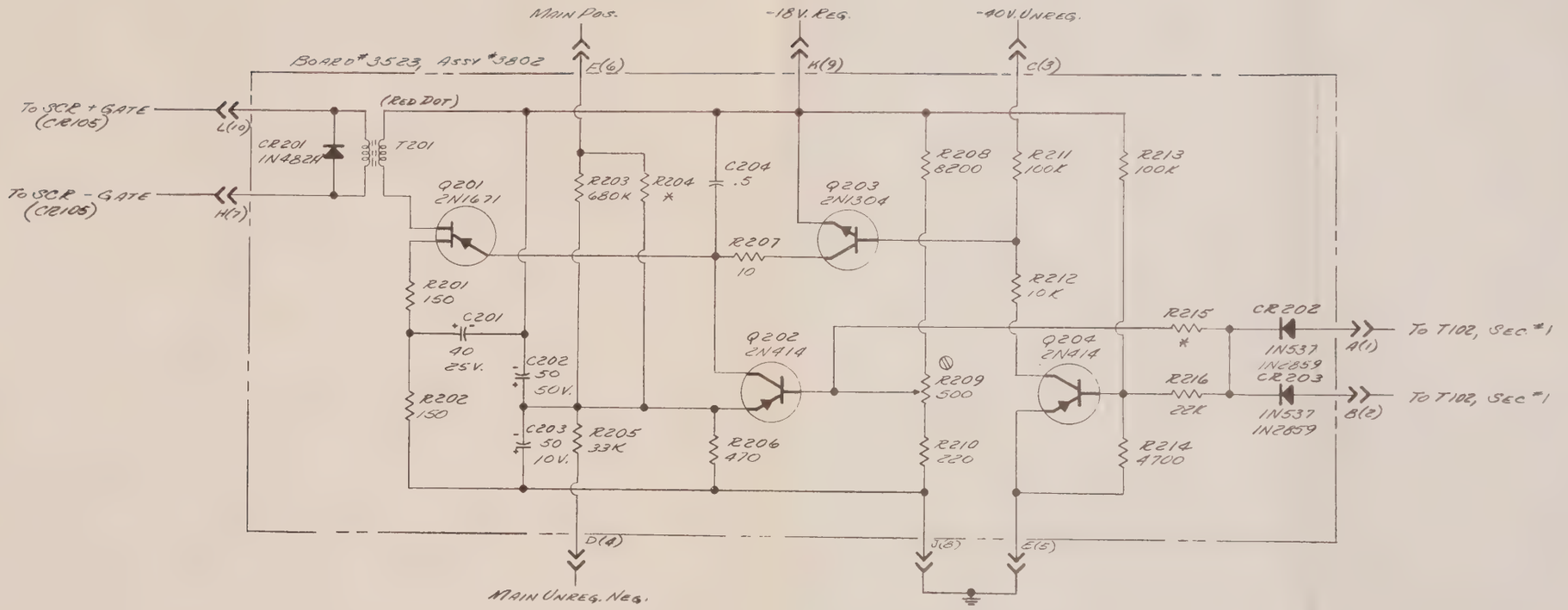
DETAILED BLOCK DIAGRAM DIODE NOISE ANALYZER MODEL 327

T-4000-A
SHEET 2 OF 2



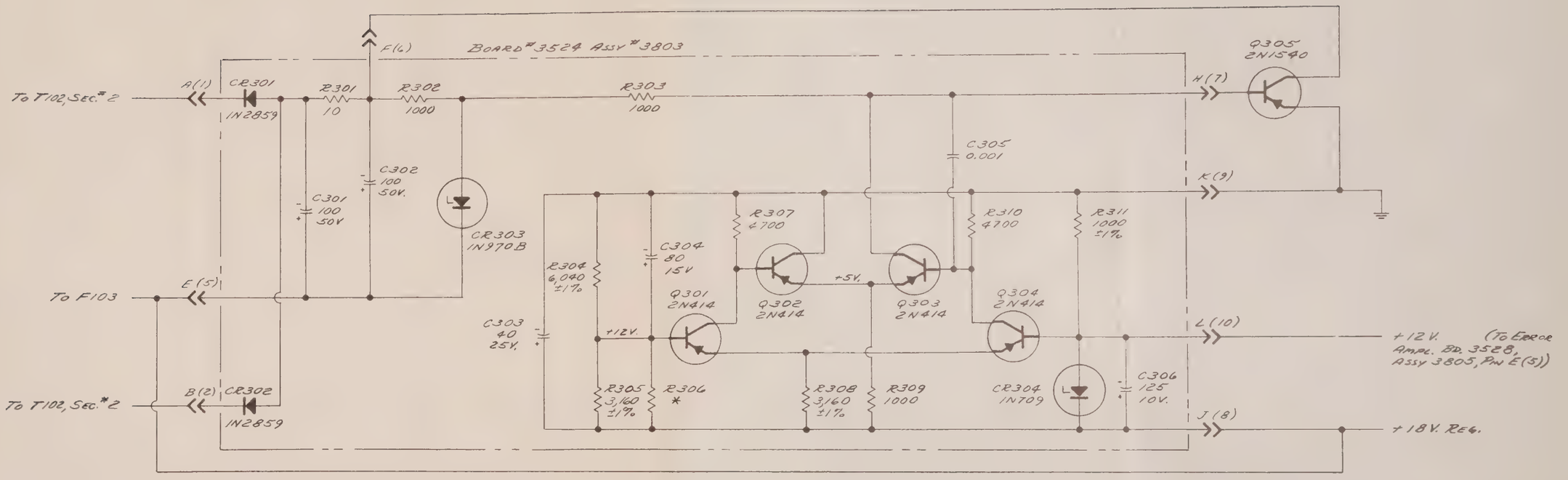
SCHEMATIC
MAIN SUPPLY & BLEED SUPPLY
MODEL 327

T-4001-C



SCHEMATIC
SCR CONTROL
MODEL 327

T-4002-B



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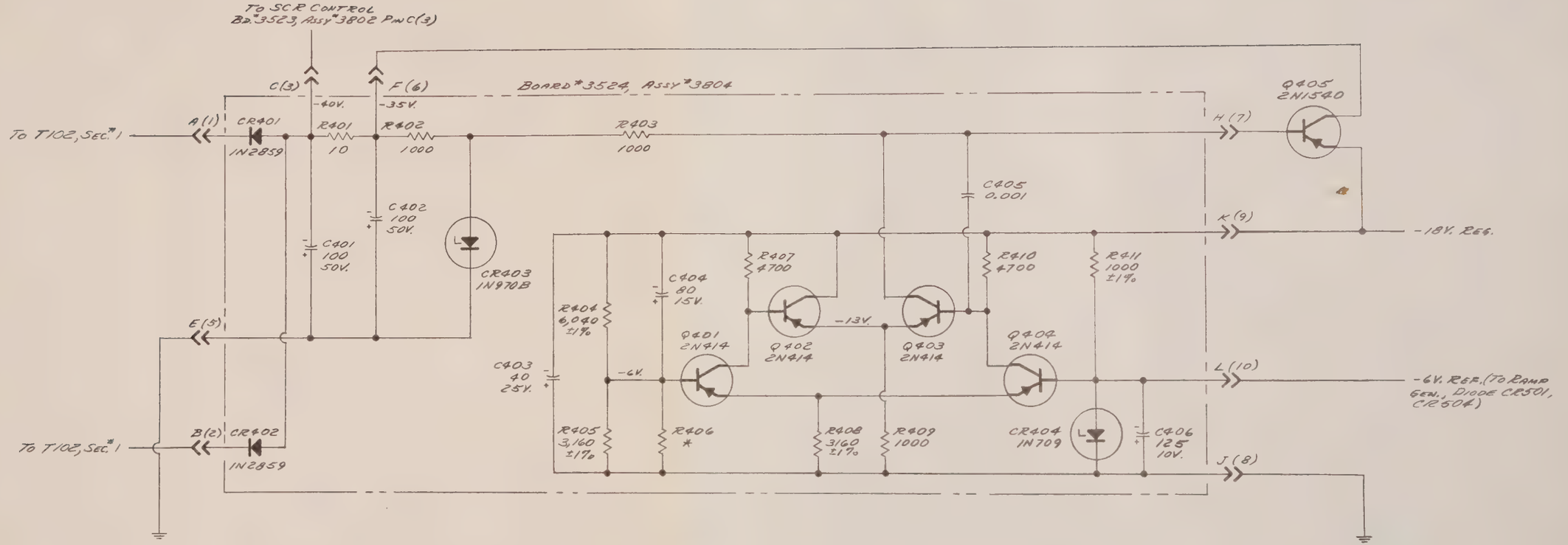
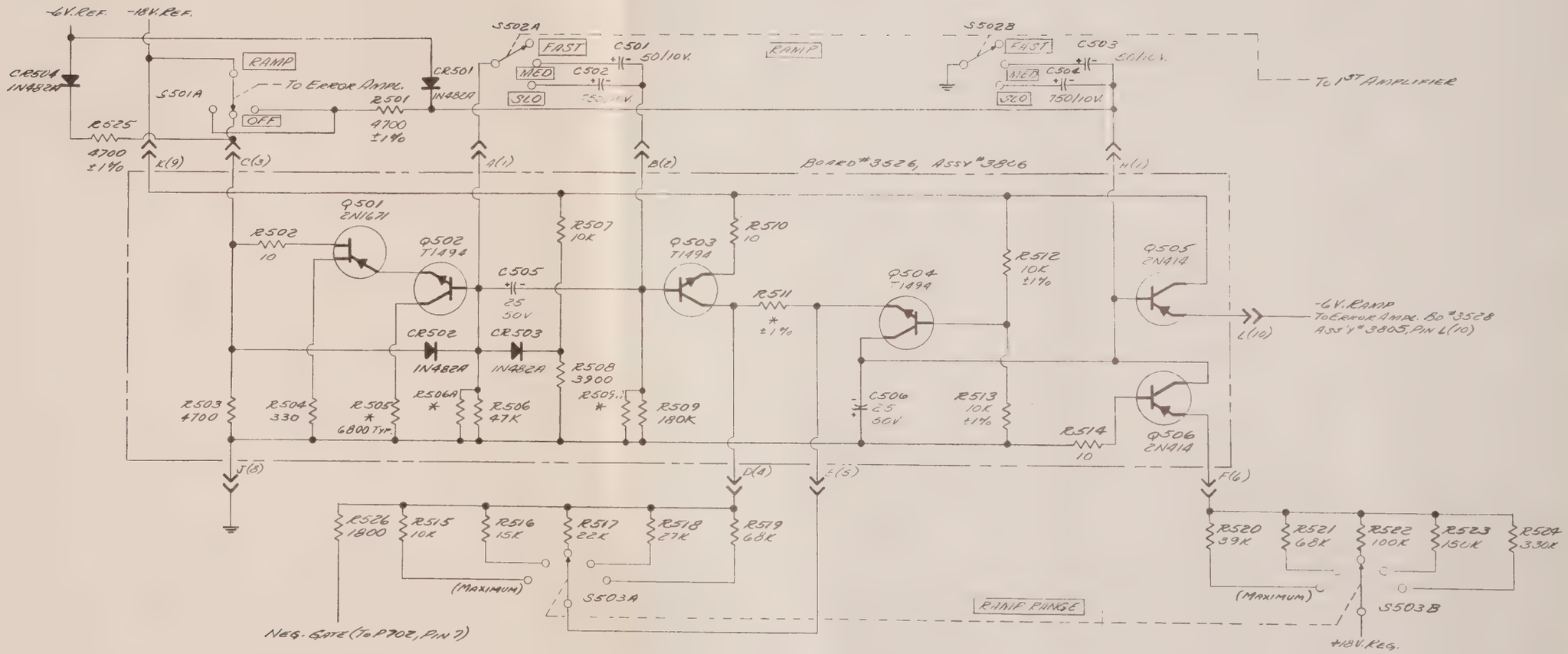
+18V. BIAS SUPPLY
MODEL 327

T-4003-C



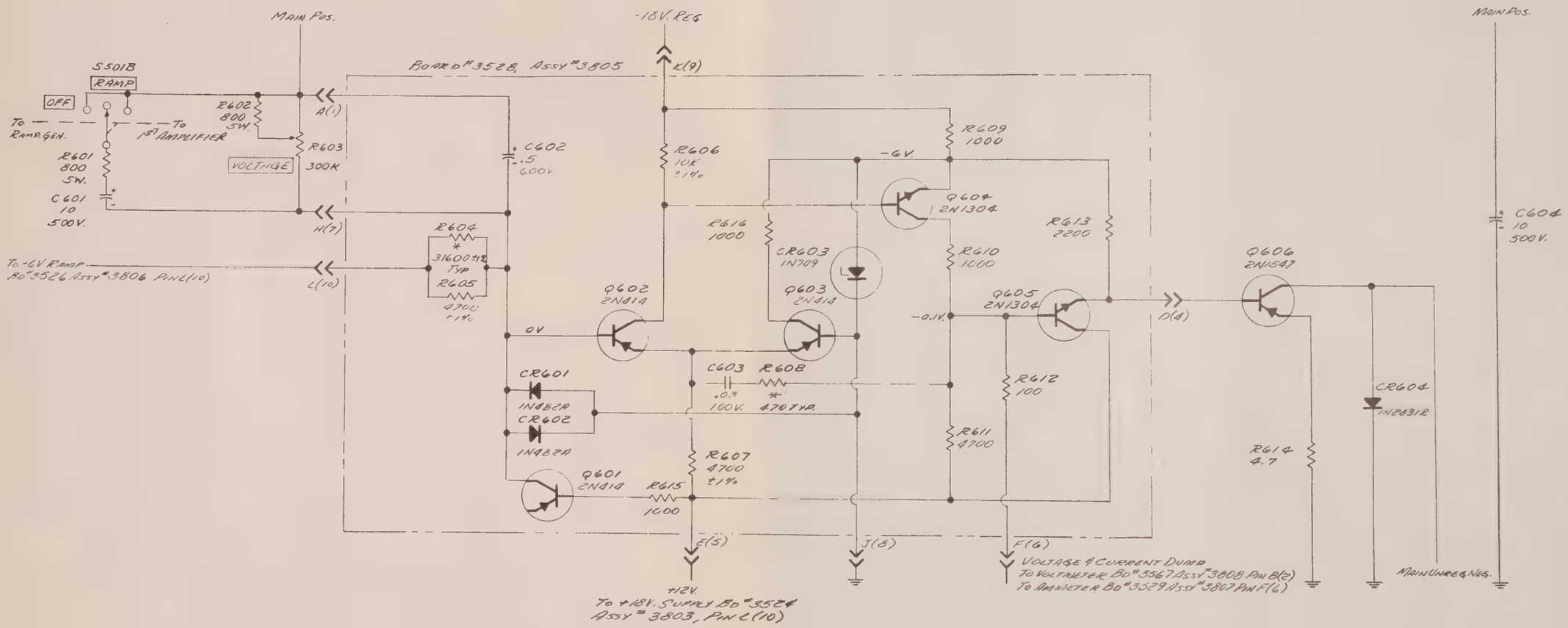
SCHEMATIC
-18V. REFERENCE & BIAS SUPPLY
MODEL 327

T-4004-D



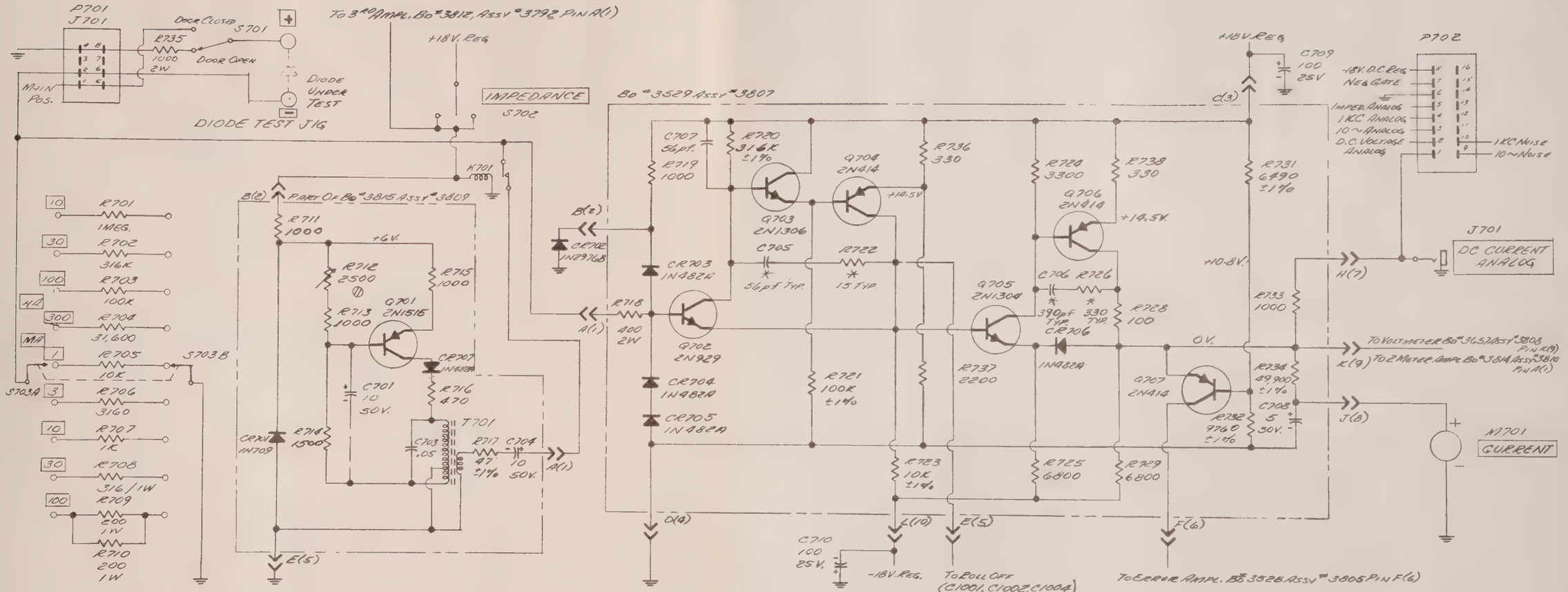
SCHEMATIC
RAMP GENERATOR
MODEL 327

T-4005-C



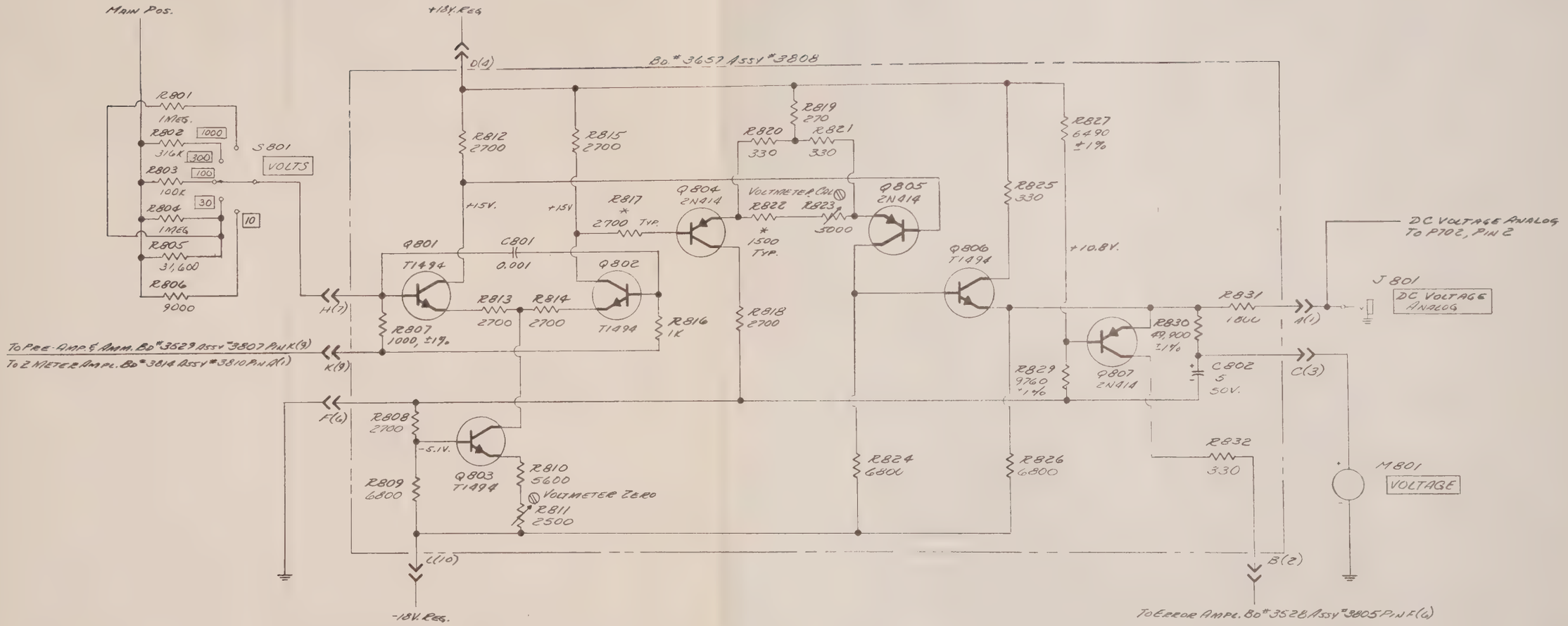
SCHEMATIC
ERROR AMPLIFIER
MODEL 327

T-4006-B



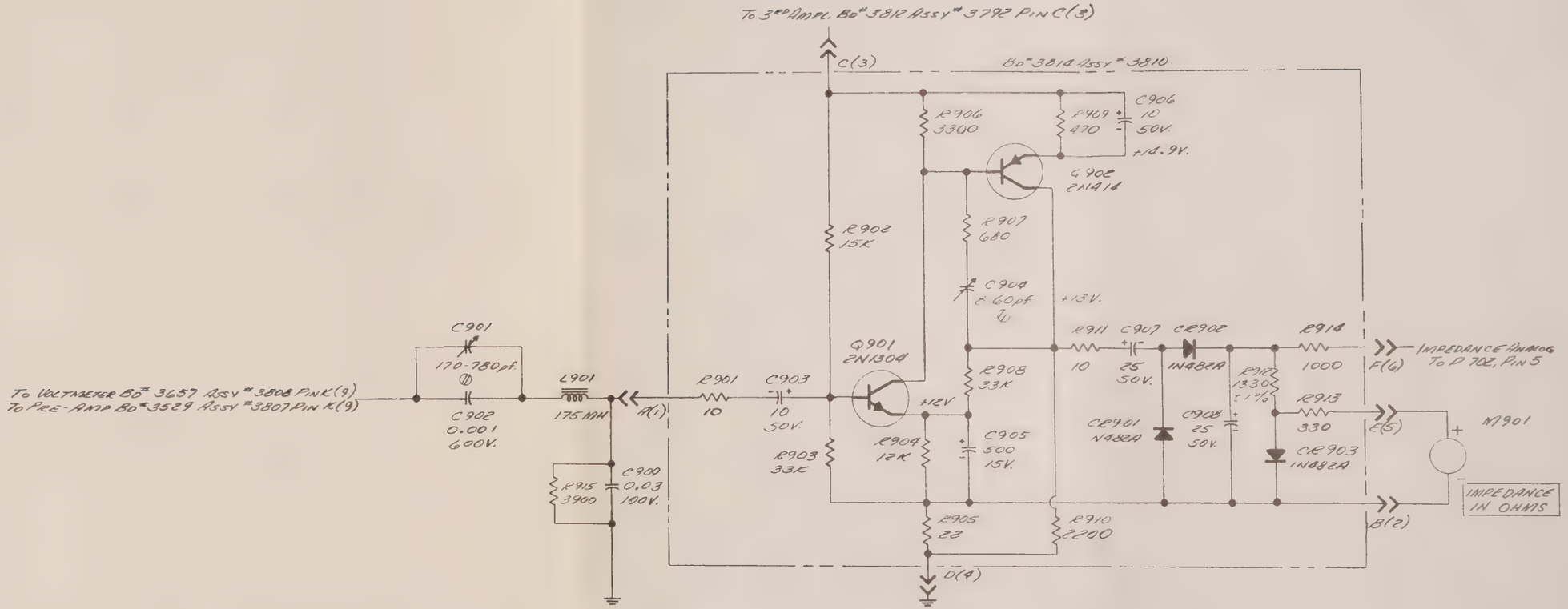
SCHEMATIC
10 KC OSC, PRE-AMPL. & AMMETER
MODEL 327

T-4007-B



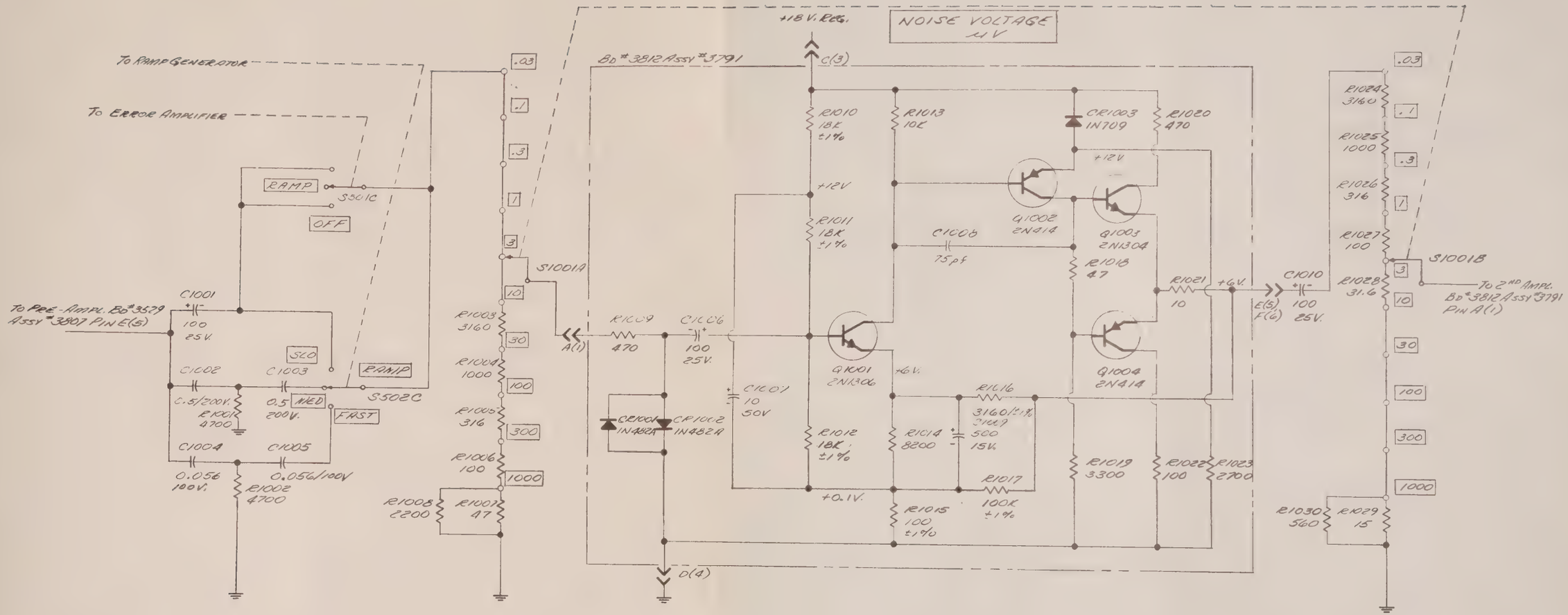
SCHEMATIC
VOLTMETER
MODEL 327

T-4008-C



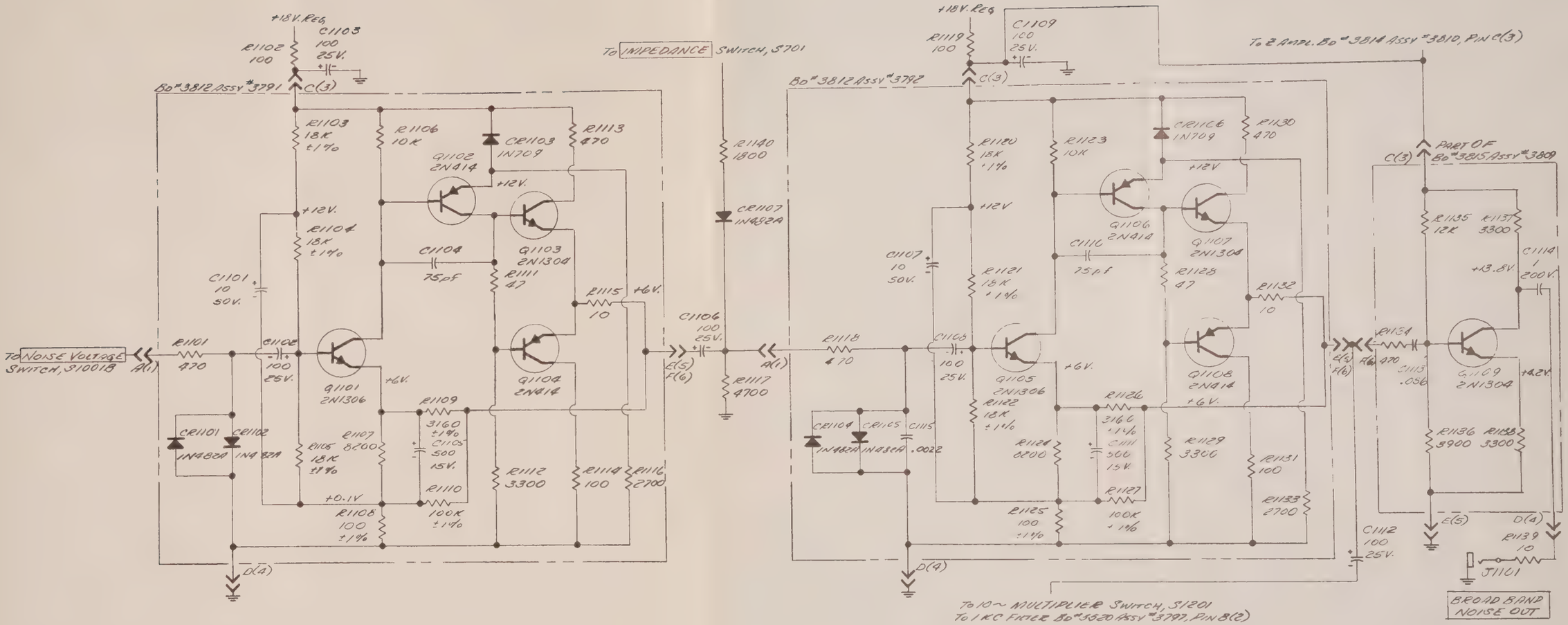
SCHEMATIC
IMPEDANCE METER AMPL.
Model 327

T-4009-B



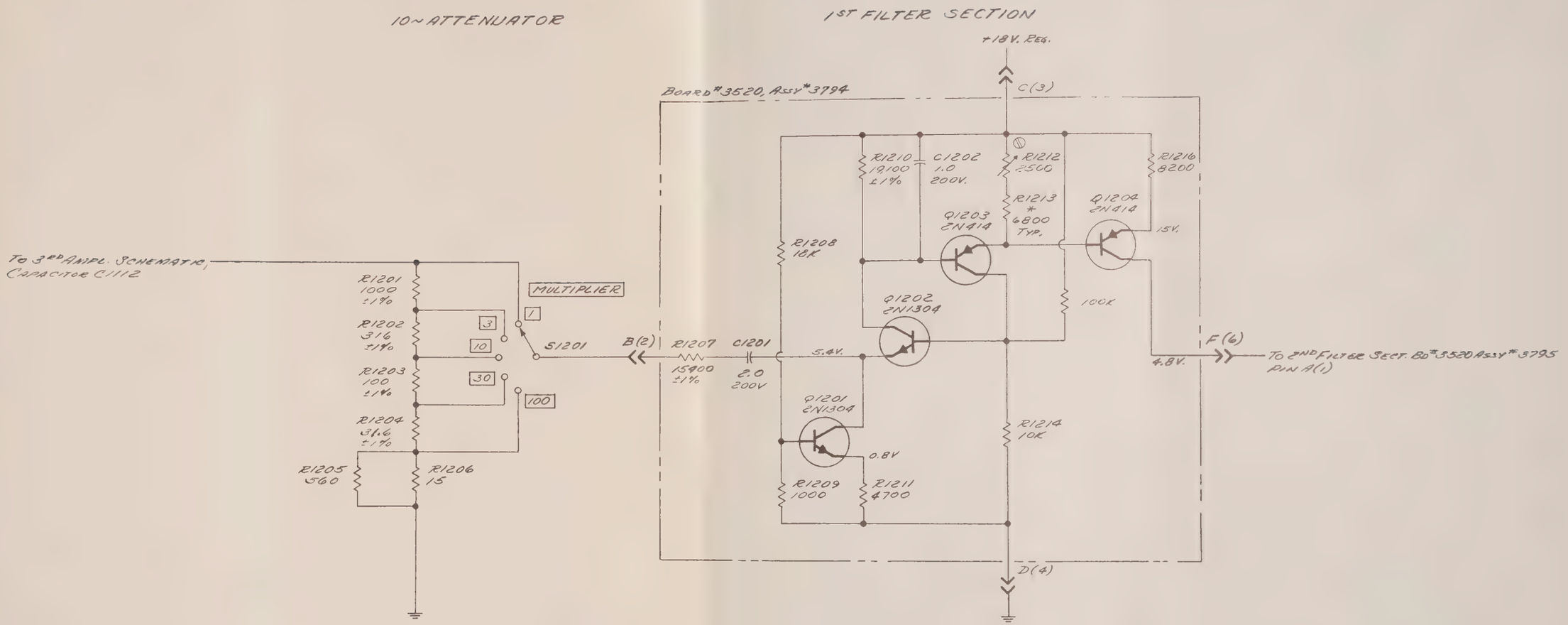
SCHEMATIC
1ST AMPLIFIER
MODEL 327

T-4010-B



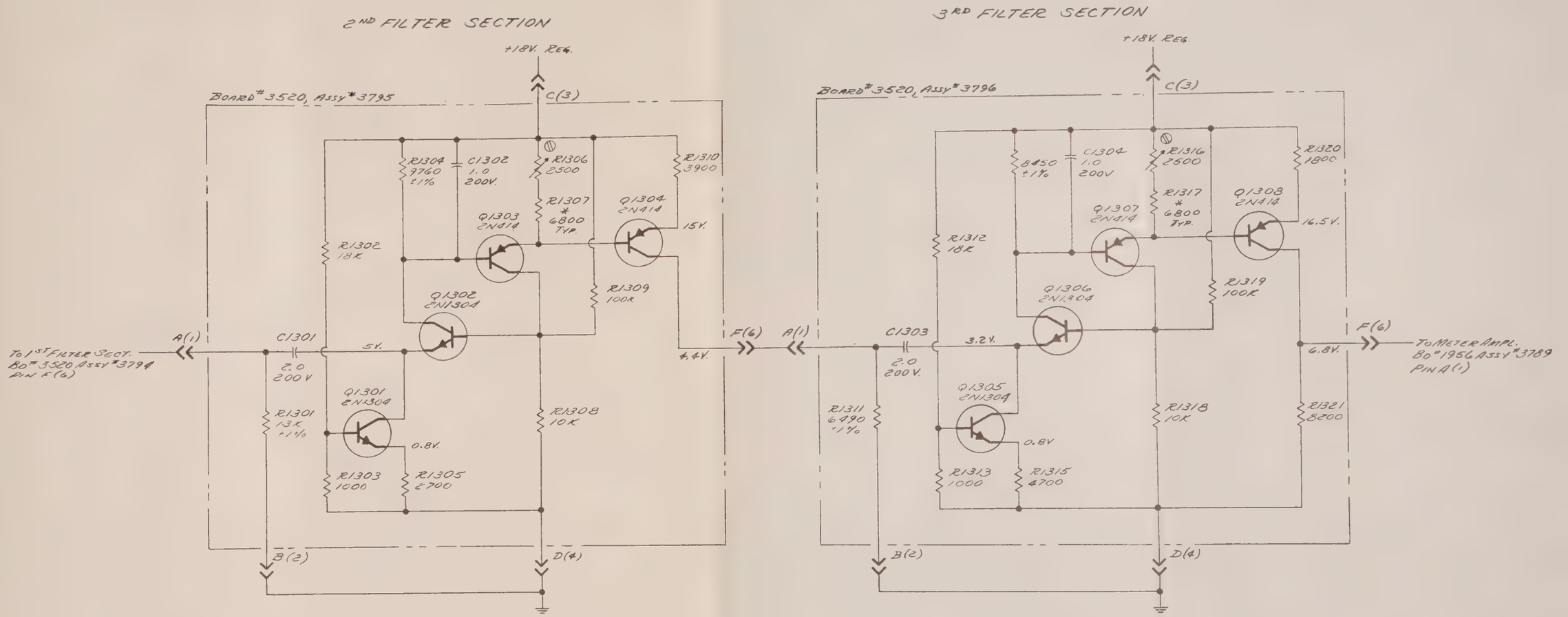
SCHEMATIC
2ND, 3RD & BROAD BAND AMPL.
MODEL 327

T-4011-C



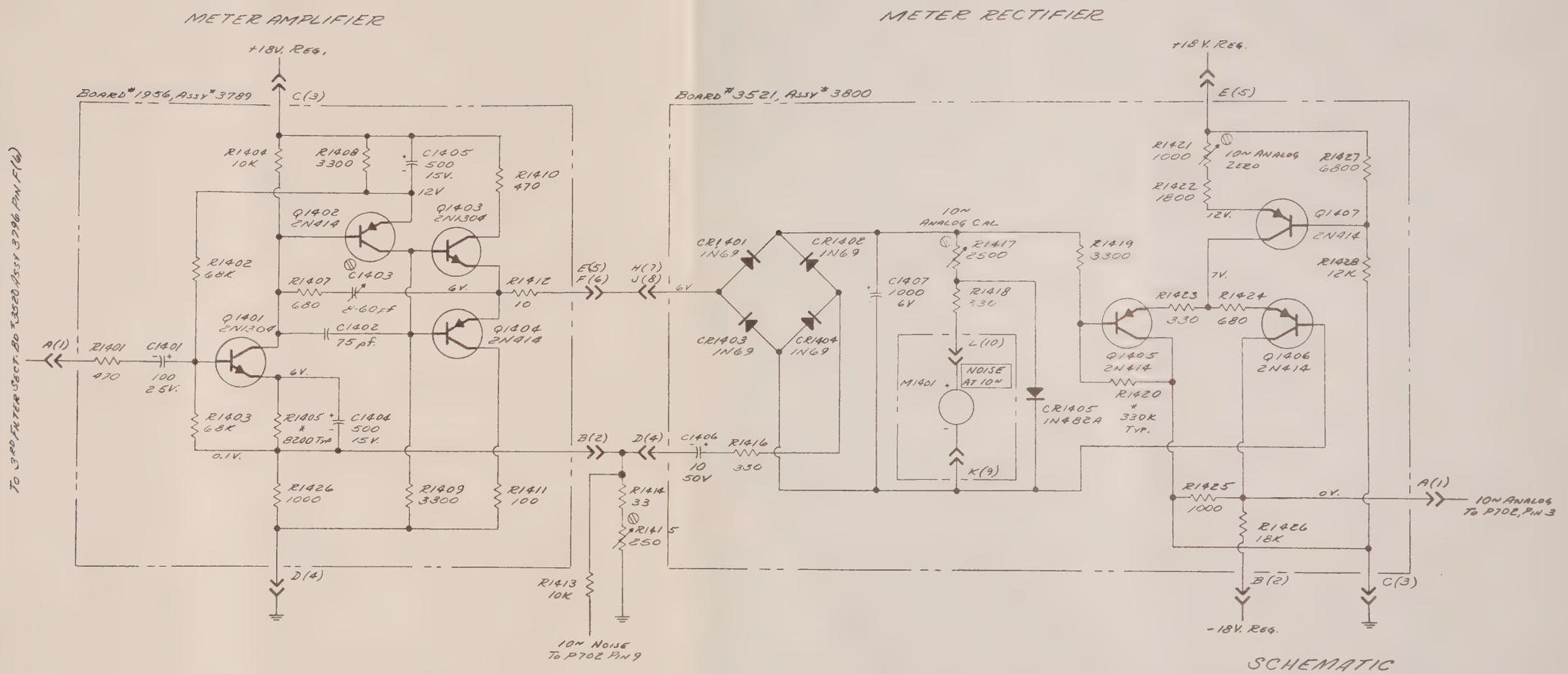
SCHEMATIC
10~ FILTER
ATTENUATOR & 1ST SECTION
MODEL 327

T-4012-B



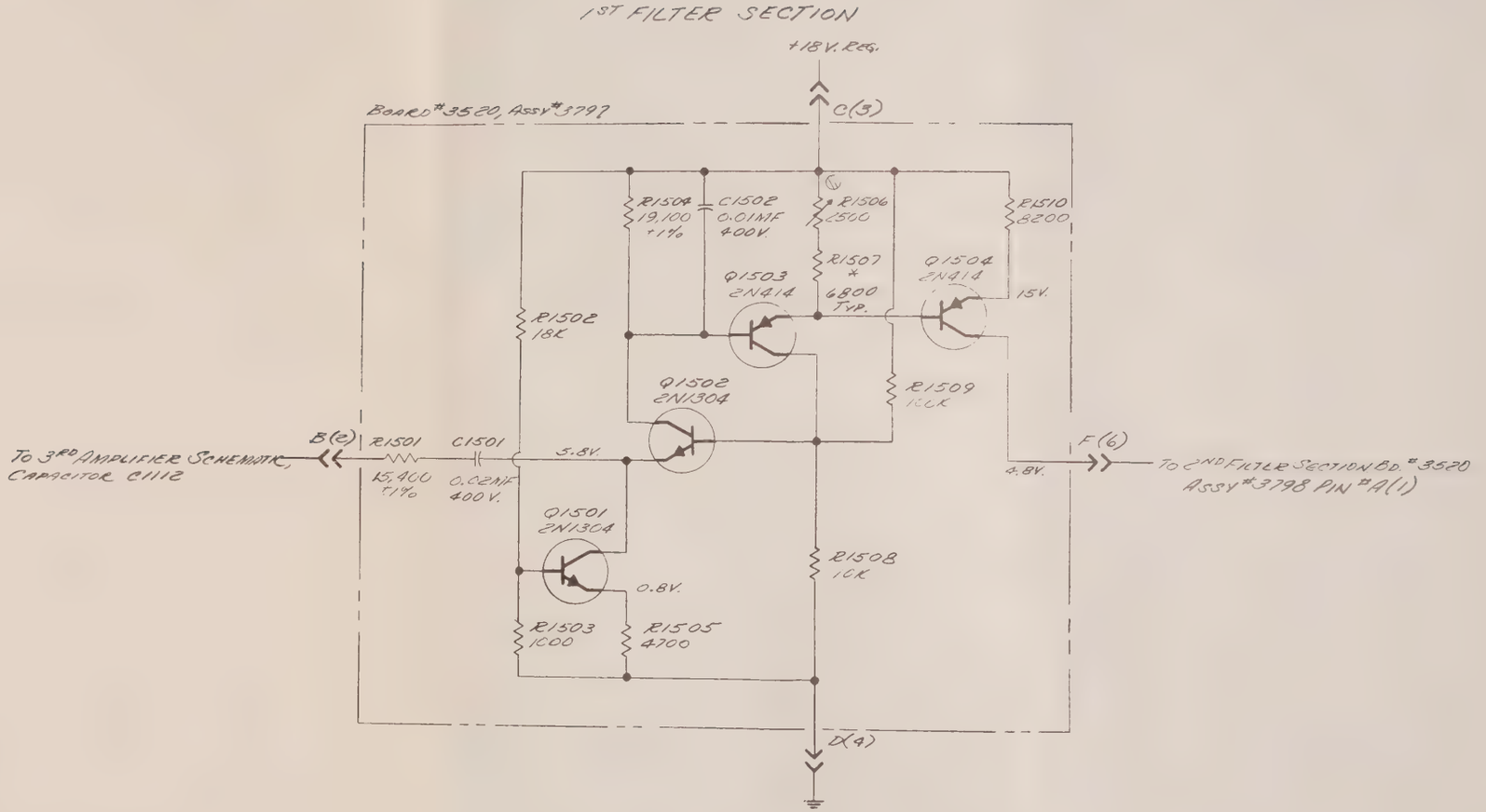
SCHEMATIC
10~ FILTER
2ND SECTION & 3RD SECTION
MODEL 327

T-4013-A



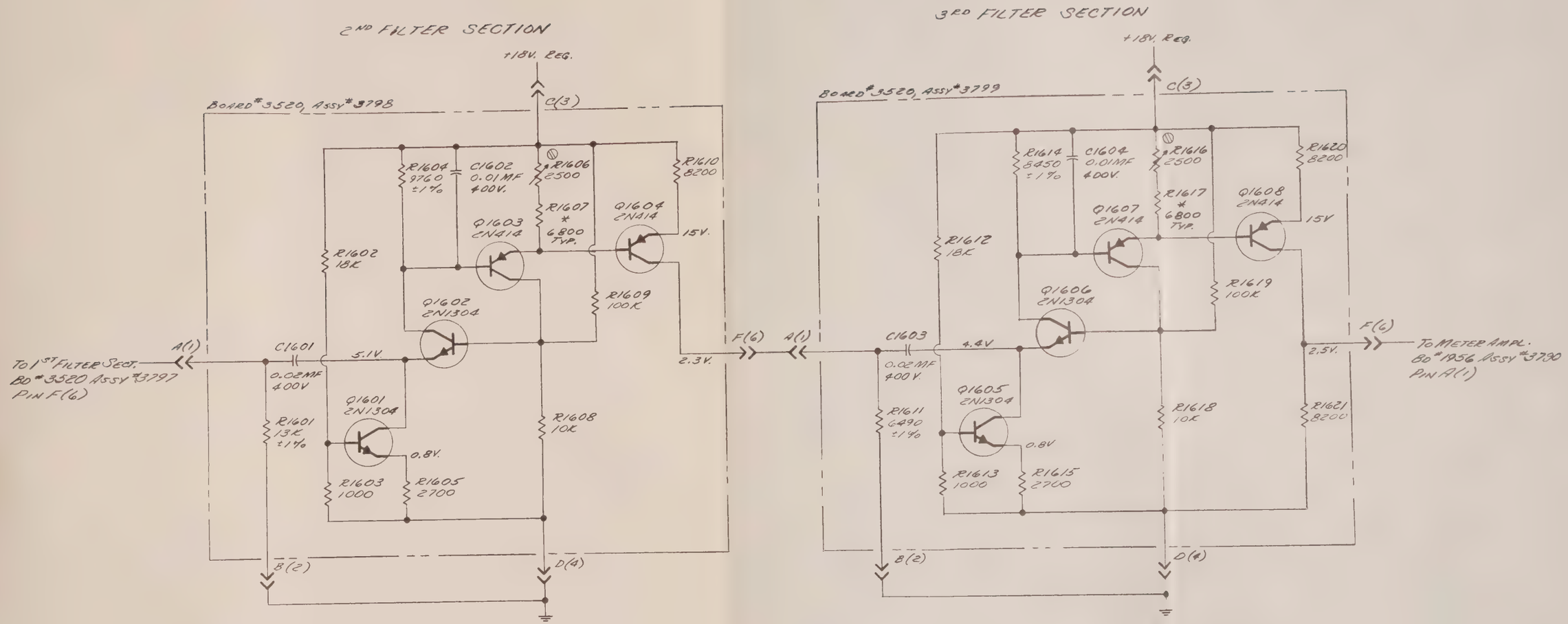
SCHEMATIC
10~ FILTER
METER AMPLIFIER & RECTIFIER
MODEL 327

T-4014-B



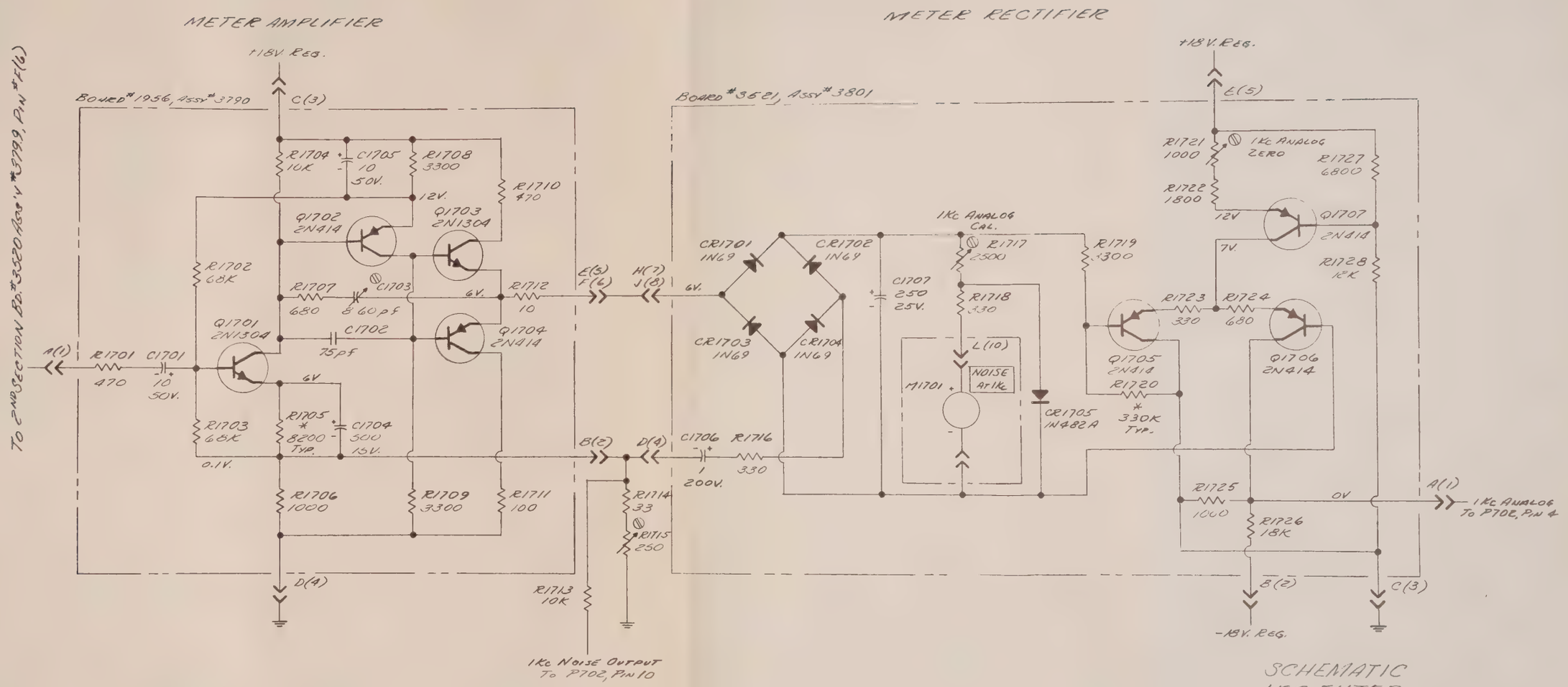
SCHEMATIC
1KC FILTER
1ST SECTION
MODEL 327

T-4015-B



SCHEMATIC
I KC FILTER
2ND SECTION & 3RD SECTION
MODEL 327

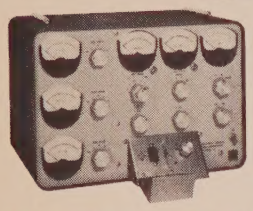
T-4016-B



SCHEMATIC
1KC FILTER
METER AMPLIFIER & RECTIFIER
MODEL 327

T-4017-B

Quan-Tech INSTRUMENTS



MODEL 310 TRANSISTOR NOISE ANALYZER

Measures noise current and voltage at 100 cps, 1 Kc and 10 Kc, as well as I_{ebo}, I_{ebo} and beta. **Noise voltage range:** 0.01 to 3 μv/root cycle, FS. **Noise current range:** 1 to 300 pa/root cycle, FS. **Collector current range:** 0.05 to 30 ma. **Collector voltage range:** 0.1 to 30 v. Measuring system automatically corrects for transistor-gain variations. **Price:** $2375

MODEL 311 TRANSISTOR NOISE ANALYZER

Similar to above, except that collector current range is from 5 to 1000 μa for noise measurement in low-collector-current devices. Beta measurement not provided. **Price:** $2575.

MODEL 312 TRANSISTOR NOISE ANALYZER

Similar to Model 310, but designed for measurement of field-effect transistors. **Drain voltage range:** 0.1 to 30 v. **Drain current range:** 0.05 to 30 ma. **Gate Bias range:** 1 v forward to 15 v reverse, continuously adjustable. Also measures transconductance. **Price:** $2575

MODEL 315 RESISTOR NOISE TEST SET

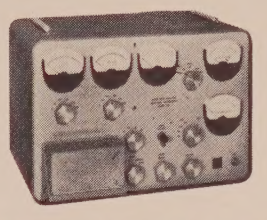
Measures noise in resistors in conformance with specifications recommended by NBS and Method 308 of MIL STD 202B. **Test-resistor range:** 100Ω to 22 meg Ω. **Measurement range:** 0.6 μv in a decade to 1000 μv in a decade. **Outputs:** Sample of noise voltage; analogs of meter readings. External cable supplied for remote location of test jig. **Price:** $1950

MODEL 2136

Similar to above, but measures resistors down to 10 Ω. **Price:** $2300

SPECIAL MODIFICATIONS

The specifications for instruments shown here are those which experience has shown meet the needs of the great majority of applications. However, in cases where highly specialized functions require variations of these characteristics, custom modifications are frequently feasible. For information on Special Modifications, write, outlining your requirements to the address below.

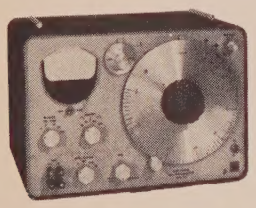


MODEL 327 DIODE NOISE ANALYZER

Measures noise in back-biased semi-conductor diodes at 10 cps and 1 Kc simultaneously. **Noise voltage range:** 0.03 μv to 1 mv/cycle of bandwidth. **Test voltage:** 0 to 500v, continuously variable. **Test current:** 0 to 100 ma, continuously variable. Internally supplied ramp automatically sweeps test current and/or voltage within maximum ratings. A wide variety of outputs for data logging, external monitoring, actuating external equipment, etc. **Price:** $2750

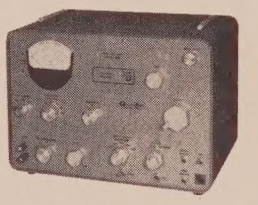
AUTOMATED NOISE TESTING

Designs exist for automatic and semi-automatic production noise-testing of resistors, diodes, transistors and capacitors. For information, write stating your particular requirements, to the address below.



MODEL 303 WAVE AND NOISE SPECTRUM ANALYZER

Frequency range: 30 cps to 100 Kc. **Bandpasses:** 10, 30, 100, 1000 cps, selectable at front panel. (100 and 1000 cps bandwidths flat-topped for simplified noise computation, greater accuracy and convenient tuning. **Sensitivity:** 100 μv to 300 v, FS. Down to 1 μv FS with accessory Model 203 preamplifier (see below). ±300 cps vernier; selection of long or short meter time constants; metering circuits compensated to minimize error from instantaneous noise pulses; overload-protected meter; analog output for external monitoring. **Price:** $1475



MODEL 304 LOW FREQUENCY WAVE & SPECTRUM ANALYZER

Frequency range: 1 cps to 5 Kc; **Bandpasses:** 1, 10 & 100 cps, selectable at front panel; **Skirt Selectivity:** 24 DB per 1/2 bandwidth; **Voltage range:** 10 μv to 100 v, FS; down to 1 μv FS with accessory Model 201B preamplifier (see below); **Tuning:** Manual or automatic; Internally supplied electronic sweep of total frequency range or of any portion; provision for external sweep; **Frequency Calibration:** Linear; **Outputs:** BFO, sample of automatic sweep, analogs of meter readings and frequency setting, phase output for phase plot on X-Y recorder. **Price:** $2150

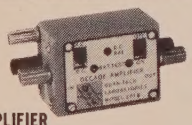
MODEL 420 RANDOM NOISE GENERATOR

Stable "white" noise output having true gaussian amplitude distribution. **Frequency range:** dc to 100 Kc; **Output voltage:** 0.01 to 1000 μv/root cycle, continuously variable, calibrated; **DC offset:** less than 10 mv at max. output. **Price:** $525

MODEL 317 AMPLITUDE DISTRIBUTION ANALYZER

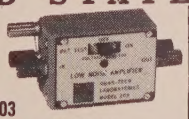
Determines amplitude-probability distribution of random signals. **Amplifier response:** 3 db down at approx. 12 cps and 1 Mc; **Switching rate:** 5 Mc; **Amplitude ranges:** 100%, 10%, 1% FS; Normal or "inverted" operation; provision for external sweep of level. **Price:** $450

SOLID STATE AMPLIFIERS



MODEL 201B DC DECADE AMPLIFIER AC OR DC COUPLED

Bandwidth: DC or 10≈ to 3Mc (3db); **Gain:** 10 (fixed); Power: Self-contained batteries; **Price:** $110



MODEL 203 LOW NOISE AC AMPLIFIER

Bandwidth: 30 cps to 100 Kc (±0.5 db); —3 db at 500 Kc; **Gain:** 100 (fixed); **Typical noise:** 5 x 10^{-9} v and 3 x 10^{-12} a per root cycle at 1 Kc. Battery powered; **Price:** $125

MODEL 205 HIGH-STABILITY DC AMPLIFIER

Bandwidth: dc to 100 Kc (0.5 db down); 3 db down at approx. 500 Kc; **Gain:** 10 (fixed); **Typical drift:** less than 250 μv at constant ambient, input shorted. External + & — 12 v required. **Price:** $105

MODEL 206 SELECTABLE GAIN AC AMPLIFIER

Bandwidth: 10 cps to 100 kc (within 0.5db); —3db at 500 Kc. **Typical noise:** 5 x 10^{-9} v and 3 x 10^{-12} a per root cycle at 1 Kc. **Gain:** 10, 100 & 1000, selectable at front panel; **Power:** 105-125 v AC or optional self-contained battery pack (automatically recharging). **Price:** $165, Batteries $25.

All prices shown are F.O.B. Boonton, N. J. Prices and specifications subject to change without notice.

Quan-Tech LABORATORIES, INC.

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